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# Summary of Fault Diagnosis Technology in Distribution Network

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## Abstract

**The structure of my country's distribution network is becoming more and more complex, and the area of power supply is getting larger and larger. After a distribution network failure occurs, it is difficult to accurately locate the fault point. More stable and efficient fault diagnosis technology is required to ensure the reliability of power supply of the power grid. . In response to the current development needs of smart grids, the technology of fault diagnosis for distribution networks is discussed, including expert system method, artificial neural network, genetic algorithm, petri net, fuzzy theory, rough set theory, Bayesian network, etc., comprehensive analysis of various The advantages and disadvantages of the methods and the applicability of these methods in application are summarized. Finally, the development prospects of the fault diagnosis technology of the distribution network under the requirements of the smart grid are discussed.**

## Keywords

**Distribution network; fault diagnosis; smart grid; development prospects.**

## 1. Introduction

The distribution network is a network that distributes electrical energy in the power system. Its main function is to reduce high-voltage electrical energy to the voltage required by users. my country's power distribution network is divided into urban power distribution network and rural power distribution network. The service coverage is wide, the development speed is fast, and users have high requirements for the quality of power supply. The power outage caused by the failure of the distribution network will affect the user's power experience, and even cause major losses to the national economy and endanger national security. Therefore, when the distribution network fails, how to quickly identify the fault point, accurately locate the fault point, and efficiently restore the power supply in the non-faulty area is the key to ensuring the reliability of the power supply of the power grid.

With the rapid development of artificial intelligence technology, more feasible and effective methods are provided for the fault diagnosis of the distribution network. There are advantages and disadvantages to the fault diagnosis methods of the distribution network, and it is necessary to select the appropriate diagnosis method for different types of faults. This article aims to summarize the common methods of fault diagnosis in distribution networks at home and abroad, compare the advantages and disadvantages of various diagnosis methods, and look forward to the development prospects of fault diagnosis in distribution networks.

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## 2. Status Quo of Intelligent Fault Diagnosis Technology for Distribution Network

### 2.1. Expert system

The expert system is an intelligent computer program system whose knowledge base contains a large amount of knowledge and experience in the field of experts. Based on this knowledge and experience, it makes inferences and judgments and simulates the decision-making process of human experts. The expert system is composed of six parts: human-computer interaction interface, knowledge base, inference engine, interpreter, comprehensive database, and knowledge acquisition. According to the known information, the expert system can continuously match the knowledge and experience of the experts in the knowledge base to obtain conclusions. The expert system model is shown in Figure 1:

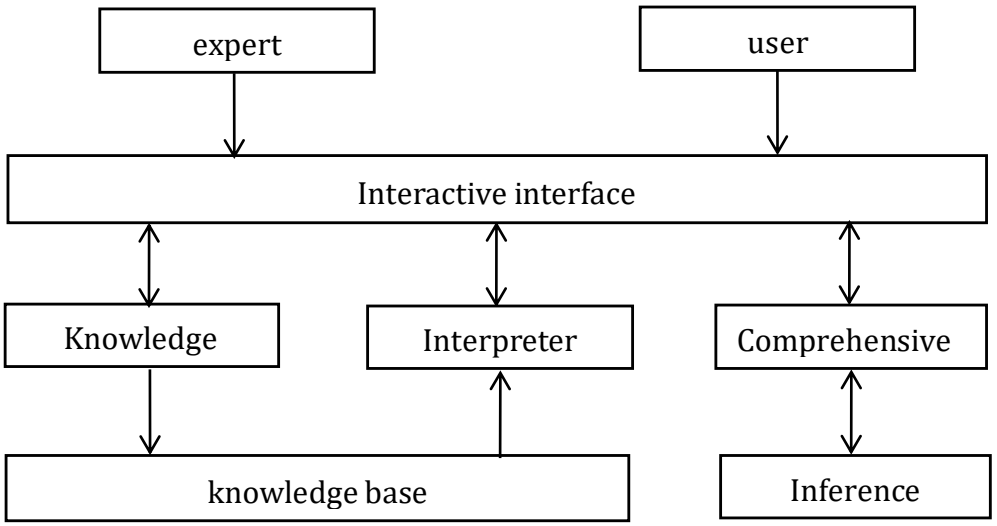


Figure 1: Expert system model diagram

### 2.2. Fuzzy theory

Fuzzy theory refers to a theory that uses the basic concept of fuzzy sets or membership functions. It includes five branches: fuzzy mathematics, fuzzy systems, fuzzy decision-making, uncertainty and information, fuzzy logic and artificial intelligence. The degree of membership is a real number [0,1], which indicates the degree to which an object belongs to a certain definition. When the distribution network fails, a large number of fault signals will be generated. It is often difficult for us to distinguish the faults caused by these fault signals. To solve the fuzzy diagnosis problem, the membership degree can be used to describe the degree to which a certain fault characteristic belongs to a certain fault. Establish fuzzy relationships.

In the distribution network fault, single-phase grounding fault is a common type of fault. Literature [2] proposes the application of fuzzy mathematics in the fault line selection of the distribution network. Use fuzzy mathematics tools to select a variety of different criteria, set the membership function and effective interval, when a fault occurs, select the line based on the above criteria to find the corresponding membership, and obtain the corresponding membership function from the decomposition theorem Set the λ cut set of A, and then perform fuzzy weighted comprehensive judgment on the elements in A according to the preset parameters and real-time data to obtain the result of the fault line selection. Finally, the line selection result is dynamically weighted and evaluated. This conformity judgment It can adapt

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to various single-phase ground faults, overcome the shortcomings of a single criterion, and improve the accuracy of line selection. Literature [3] proposed a method of fault line selection based on fuzzy theory for multi-criteria fusion in distribution network. This method performs data fusion based on three line selection methods: attenuated DC component method, high frequency modal method and 5th harmonic component method. According to the different characteristics of the zero sequence current of the normal line and the fault line of the system, the membership function of the line selection is constructed. This method is less subject to external interference, and has strong sensitivity and accuracy.

Using fuzzy theory to diagnose faults in the distribution network can obtain more solutions with different priority levels, and has a strong ability to analyze uncertain fault types. Fuzzy theory is often combined with other artificial intelligence methods to improve its fault tolerance. The optimization of the membership function is still a problem worthy of study.

## 2.3. Petri Net

Petri nets are mathematical representations of discrete parallel systems. It has both strict mathematical expressions and intuitive graphical expressions. A classic Petri net is composed of places, transitions, input functions, and output functions. Its model is shown below:

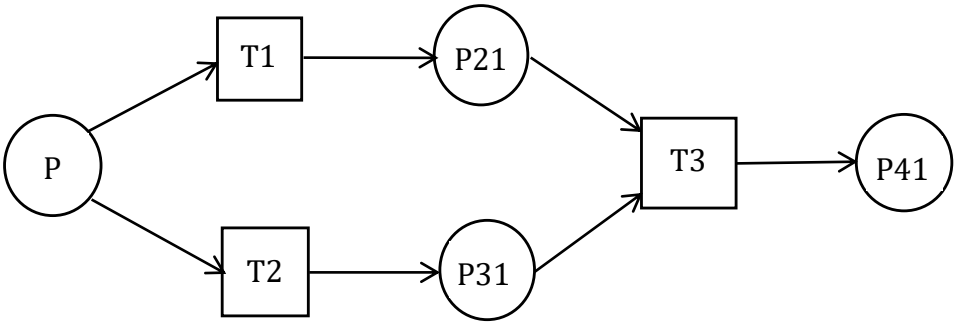


Figure 2:Classic Petri net model diagram

In the above figure, the circular node is the place, the square node is the transition, and there is a directed arc between the place and the transition. The dynamic object in the place is a token, and the token can be moved from one place to another place. Petri net is suitable for fault diagnosis of small and medium-sized distribution network. When the scale of the distribution network fault is too large, the structure of Petri net is very complicated, which will affect the diagnosis speed [4].

Literature [5] realized the design of the Petri model of the distribution network system by systematically combining multiple Petri network models of a single protection system and a current detector. In the case of data transmission errors, rapid fault diagnosis can be performed. This method is suitable for fault diagnosis of distribution networks containing distributed power sources. It can effectively reduce the complexity of data analysis and realize fault diagnosis under the premise of ensuring the safe operation of the power system. Quick assessment. Literature [6] proposed a Petri net-based fault section location and fault pattern recognition method. This method modifies the voltage criterion in the section location of the distribution network. In the fault pattern recognition, different faults in the distribution network are analyzed. Type characteristics.

The Petri net model still has certain defects in the fault diagnosis of the distribution network. The current status of multiple configurations of power grid protection devices, the difference

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of the action time between the protection devices, and the abnormal performance of the protection devices will cause the fault diagnosis based on the Petri net to be incorrect.

## 2.4. Rough set theory

Rough set theory is a data analysis and processing theory, which was first proposed by researchers represented by Polish mathematician Z.Pawlak. Rough set theory can deal with inaccurate, inconsistent, and incomplete information. It does not need to provide any prior knowledge other than the data set to be processed by the problem, and it has strong complementarity with other uncertain problems. For example, fuzzy theory, neural network, genetic algorithm, etc. Literature [7] combines rough set theory with BP neural network to diagnose faults in the distribution network, using rough set information system decision tables as the main tool, and using BP network to learn and train the simplest rule set to form a rough set -The model structure of the neural network. The diagnosis time is shortened and the accuracy is improved. The method has better fault tolerance and higher generalization ability. Literature [8] gives a general method for reducing the decision table and finding the minimum reduction in rough set theory. The method uses the protection and circuit breaker signals as the condition attribute set for fault classification, and uses the reduced form of the decision table to extract the diagnosis rules, and realizes the fault diagnosis of the distribution network in the incomplete alarm mode.

Rough set theory also has its shortcomings in the application of fault diagnosis in distribution network [9]. To improve the feasibility of reduced rules, a large amount of decision table information needs to be collected. In actual power grids, a large number of fault samples are collected. It will bring considerable workload, and in large-scale power grids, there will even be a problem of "combination explosion".

## 2.5. Bayesian network

Bayesian network is currently one of the most effective theoretical models in the field of uncertain knowledge expression and reasoning. A Bayesian network is a directed acyclic graph consisting of variable nodes and directed edges connecting these nodes. The nodes represent random variables, and the directed edges represent the relationship between nodes. Bayesian network is an uncertain causal association model, which has a strong ability to deal with uncertain problems, and can learn and reason under the condition of limited, incomplete and uncertain information. The Bayesian network can incorporate various information related to the distribution network fault diagnosis and maintenance decision-making into the network structure, and process it uniformly in the way of nodes, which can effectively integrate the information according to the correlation relationship.

In [10], a fault diagnosis of distribution network based on rough set and Bayesian network is proposed. Using rough set theory, the large amount of fault information collected is simplified, and the decision rules are derived from the fault sample space. After obtaining the reduced decision table, a Bayesian network model is established based on the decision table. This method overcomes the shortcomings of incorrect diagnosis results caused by missing information, and improves the reliability of the diagnosis results.

Bayesian network can visually express the results of fault diagnosis, but it also has shortcomings. There are many types of faults in the distribution network, and the fault characteristics are also different. It is difficult to obtain the prior probability, and when the size of the distribution network is When the structure is large and the structure is complicated, the modeling is more difficult.

## 2.6. Artificial neural networks

Artificial neural network is an algorithmic mathematical model that imitates the behavioral characteristics of animal networks and performs distributed and parallel information

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processing. Its main task is to build a practical artificial neural network model based on the principle of biological neural network and the needs of practical applications. Artificial neural networks are characterized by large-scale parallel processing, distributed storage, flexible topology, highly redundant and nonlinear operations.

At present, the most widely used in the fault diagnosis of distribution network is the multi-layer perceptron neural network theory of BP algorithm. Literature [11] proposed the application of optimized BP neural network in the fault location of distribution network. This paper uses the fault information collected by FTU, and analyzes and locates the fault information using cloud theory and genetic algorithm optimized BP neural network, which improves the accuracy and effectiveness of fault location. Literature [12] proposed a research on the fault diagnosis of distribution network based on the dragonfly-artificial network algorithm. This paper combines the dragonfly algorithm and the initial value and threshold value of the neural network to optimize the parameters and improve the fault diagnosis of the distribution network. Accuracy. The fault identification method of distribution network based on bp neural network proposed in [13] has a simple principle of fault location method, which is relatively convenient to implement, does not require an accurate objective function, and can locate single and multiple faults, but it is not applicable For large-scale distribution networks.

The neural network has a strong learning ability and can improve its fault tolerance when applied to the fault diagnosis of the distribution network. However, the neural network requires a large number of samples for its learning. If the system structure changes, it needs to relearn with new samples, and the diagnosis The results lack interpretation ability, and it is difficult for operators to analyze the diagnosis results. Literature [14] proposed that neural networks have many problems in fault diagnosis, and their performance depends on whether the samples are complete, but it is difficult to obtain a complete sample set of large power systems; the function of interacting with symbol databases is weak; they are not good at handling heuristics Knowledge; I don't know how to ensure the rapid convergence of neural network training and avoid falling into the local minimum; I lack the ability to explain my own behavior and output results. Therefore, the neural network is not suitable to be used alone in the fault diagnosis of the distribution network, and is often combined with other fault diagnosis methods.

## 2.7. Genetic algorithm

Genetic algorithm is a computational model that simulates the biological evolution process of natural selection and genetic mechanism of Darwin's biological evolution theory. It is a method to search for the optimal solution by simulating the natural evolution process. The characteristic of genetic algorithm is to search from the set of problem solutions, covering a large area, which is conducive to global selection. Since the overall search strategy and optimized search method of genetic algorithm do not depend on gradient information during calculation, only the objective function and corresponding fitness function that affect the search direction are needed, so genetic algorithm has strong robustness to the types of problems. Can be used in many research fields [15]. When genetic algorithm is applied to complex distribution network faults, protections, and circuit breaker malfunctions, it can give multiple possible diagnosis results of global optimal or local optimal.

Literature [15-16] proposed the application of improved genetic algorithm in the fault location of distribution network with distributed power sources [17-19]. According to the fault current information collected on the FTU of each switching element, a mathematical model for fault location is built, and the distribution network is partitioned. The simulation is carried out by MATLAB. The results show that the improved genetic algorithm is useful in the distribution network with distributed power sources. Better fault tolerance, and the algorithm's computational efficiency and accuracy are very high. Literature [21] proposed a distribution

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network fault location technology based on an optimized genetic algorithm. The genetic algorithm is characterized by strong search ability, short search time, and simple process, but the algorithm initially depends too much on population selection and cannot be used in time. Feedback. The optimized multiple population genetic algorithm (MPGA) can locate single-point and multiple-point faults in the distribution network, and can reduce the time required to obtain a more accurate optimal solution.

At present, genetic algorithm has been widely used in the fault diagnosis of distribution network, but genetic algorithm also has its shortcomings. It has no effective quantitative analysis method for the accuracy, feasibility and computational complexity of the algorithm. It is also a difficult point to build a reasonable fault model of the distribution network.

### 2.8. Other optimization algorithms

The optimization algorithm transforms the diagnosis problem of the distribution network into an optimized solution model. At present, there are many types of optimization algorithms, such as greedy algorithm, particle swarm algorithm, simulated annealing algorithm, ant colony algorithm, etc. Different optimization algorithms have their own characteristics, and you need to choose a suitable optimization algorithm according to actual needs. The fault diagnosis method of distribution network based on optimization algorithm can give multiple possible diagnosis results of global optimal or local optimal under the condition of incomplete information. The key to the realization of the distribution network fault diagnosis model is how to form the objective function according to the protection configuration principle and the logical relationship between the protector and the circuit breaker. Combining multiple optimization algorithms for solving is the development trend of future distribution network fault diagnosis.

Literature [22] proposed an active distribution network fault location method based on the moth algorithm. When there is a strong light source near the moth, the moth is affected by the scattering of the strong light source and will spirally fly around the strong light source. So Seyedali Mirjalili proposed an optimization algorithm for moths to extinguish the fire. In [23], a research on fault location of distribution network based on improved ant colony algorithm is proposed. The IA algorithm is used to optimize the selection of the random initial factors of the ACO algorithm to establish an IA-ACO model. The comparative experiment verifies that IA-ACO has a faster convergence speed and better optimization ability than the traditional ACO algorithm. Literature [24] proposed an active distribution network fault location method based on artificial fish school algorithm. This algorithm is a new type of bionic intelligent algorithm. The place with the largest number of fish schools in the water is generally the place with the most nutritious food. Based on this feature, artificially simulate the behavior of fish schools to achieve global optimization. Improve the accuracy of fault location in the active distribution network.

## 3. Prospect of Fault Diagnosis Technology in Distribution Network

The distribution network has the characteristics of multiple voltage levels, diverse operation modes, complex operating environment, frequent feeder switching, and a large number of branches. Therefore, it is difficult to meet the requirements of distribution network diagnosis by relying on a single method. The combined application of two or more diagnostic methods in the distribution network fault diagnosis has become the trend of future distribution network fault diagnosis [25-27]. Nowadays, multi-source information extraction has been realized. Various methods such as fault information recording, data collection, fault location, expert system, etc. To achieve fast and accurate fault diagnosis, the future fault diagnosis combines multiple methods and cannot do without manual work. Intelligent innovation and application [28-29]. Literature [30] combined Petri net with particle swarm algorithm and applied it in the

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fault location of distribution network. This paper proposes to use the parallel inference feature of Petri nets to optimize the particle swarm algorithm, which makes up for the defect that the particle swarm algorithm may fall into local extreme points in the calculation process, improves the fault tolerance of the active power distribution system fault search, and shortens the running time. Literature [31] proposed a fault location method for distribution network that organically integrates MBD consistency reasoning and Petri nets. First, by abstracting the original system, establishing and analyzing the redundant relationship, searching for the candidate of the minimum conflict set, using the BPSD intelligent algorithm to calculate the minimum collision set, and judging the faulty component. Then according to the Petri net theory set various fault characteristics, establish the fault identification model, and finally judge the fault type. This method can quickly and accurately diagnose faulty components and identify fault types.

At present, the intelligent diagnosis technology based on the fault information returned by the FTU [32] has become mature, but only relying on the fault information uploaded by the FTU cannot achieve precise positioning, and the ability to diagnose complex faults is poor. There is a fault diagnosis method based on traveling wave theory [33], which can realize accurate fault location. Literature [34] proposed a fault location system for multi-power distribution network supported by traveling wave theory. The system is composed of a fault traveling wave location information processing subsystem and a fault traveling wave location subsystem. When the subsystem receives a fault traveling wave When the positioning subsystem calls information, it transmits the information to the fault traveling wave positioning subsystem. Using the Agent idea and traveling wave theory to design the fault traveling wave location subsystem, through the mutual cooperation and communication between multiple agents, the fault location of the multi-power distribution network is finally realized, which improves the accuracy and efficiency of fault location. However, the fault diagnosis based on traveling wave theory is inadequate in its high cost and low economy. In the future, the prospect of fault diagnosis methods based on traveling wave theory is very good. How to reduce the number of installations and reduce production costs is the key to whether this method can be popularized.

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