Hierarchical Information Fault Diagnosis Method for Power System Based on Fireworks Algorithm

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Abstract

Power system fault diagnosis is an important means to ensure the safe and stable operation of power system. According to the specific situation of China's current power grid automation level, a hierarchical fault diagnosis method based on switch trip signal, protection information and fault recording information is proposed. This method can not only diagnose simple fault and complex fault, but also judge fault type and phase, and complete fault location, which provides reliable guarantee for operators to quickly remove fault and resume operation. The diagnosis method based on this principle has good application effect in simulation test.

Keywords: Fireworks algorithm, power system, hierarchical fault diagnosis.

1 Introduction

Power system users have higher and higher requirements for power reliability. However, due to operation, maintenance, insulation aging and other reasons, power system failure is inevitable. In order to quickly monitor and eliminate

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faults, ensure the safe and stable operation of the system, and enhance the reliability and continuity of power supply, a high-quality fault diagnosis system is needed. The problem of fault diagnosis in power system is to identify fault components and misoperated protections and circuit breakers by using the collected information as much as possible, and the identification of fault components is the key problem. Because this process is difficult to describe with traditional mathematical methods, and artificial intelligence technology is widely used in this field because it is good at simulating the process of human processing problems, is easy to consider human experience and has a certain learning ability. At present, a lot of work has been done on the theory and practice of power system fault diagnosis at home and abroad, such as expert system, artificial neural network, fuzzy theory, genetic algorithm and Petri network, and much progress has been made [1]. The expert system is intuitive and has strong explanatory ability, but it is difficult to obtain a complete knowledge base, has no learning ability and poor fault tolerance. Artificial neural network has the ability of learning and fault tolerance, and the calculation between neurons is relatively independent, which is convenient for parallel processing. However, the convergence speed of its learning algorithm is generally slow. After learning, if the system structure changes, new samples need to be added to relearn. In addition, Ann has a good interpolation effect after learning, but the error may be large when extrapolating. The general fuzzy system adopts a structure similar to the expert system, so it also has some inherent advantages and disadvantages of the expert system, but increases the fault tolerance. From the perspective of optimization, the genetic algorithm can basically solve the problem of fault diagnosis, especially in the case of multiple faults or misoperation of protection and circuit breaker. It can give multiple possible global optimal or local optimal diagnosis results, but the speed is slow, and it is difficult to build a perfect mathematical model of fault diagnosis [2]. In recent years, it is also a trend to use Petri net to solve the problem of fault diagnosis from analyzing and simulating the action logic of protection system.

In this paper, a hierarchical information fault diagnosis method is proposed to improve real-time performance and make flexible use of information. Based on the integrity and reliability of the information, the collected information is divided into three layers according to the time priority of the current power system communication protocol, that is, the switch displacement information of the first layer, the protection action information of the second layer, and the wave recording information of the third layer. The first layer information can be used for basic fault diagnosis. At this time, the delineation of power failure area only uses remote signaling. Using the information of the first layer and the second layer can make more reliable fault diagnosis. At this time, telemetry and network parameters can be used to identify the circuit breaker status, and the outage area can be determined more reliably. The most reliable fault diagnosis can be made by using all three layers of information. At this time, it can determine whether the protection should act and the actual state of the circuit breaker, and the program can flexibly select the fault diagnosis method according to the specific situation. Users can also choose freely, which will make the software more adaptable. In contrast, the fireworks algorithm is globally convergent, and the search efficiency is much higher than the general random algorithm, which shows its unique advantages in solving multivariable, nonlinear and discontinuous problems. Although the fireworks algorithm generally has a large number of iterations, through the division of the outage area, the initial individual is formed according to the relevant protection circuit breaker information, and the application of adaptive technology, the scale of search space is effectively reduced, the search efficiency is improved, and at the same time, the algorithm is global, and the results are better.

2 Research on Fault Diagnosis Method of Hierarchical Information in Power System Based On Fwa

At present, power system fault diagnosis mainly relies on three kinds of information: switch displacement information, protection action information and recorder information. Layering refers to the layering of information collected by power grid dispatching terminal. Due to the difference in the amount of information, the arrival time of information is different, so the method of fault diagnosis layer by layer is adopted [3].

The first layer of information is the switch displacement information from SCADA, the second layer is the protection information, and the third layer is the fault recorder information. In this way, the fault diagnosis can be divided into the following steps:

- First, the fault area is judged by the switch information. Because in any SCADA system, the switch displacement information can be obtained quickly and reliably, and the fault area or equipment is isolated by the trip switch at any time, the minimum amount of switch information is the first to arrive at the substation, so it can quickly locate the power equipment with simple fault or find out the power failure area [4].

- For single or multiple blackout areas caused by complex faults, the computer automatically and purposefully queries the protection information of relevant plants or substations, and the computer that collects the protection information automatically responds. If the fault power equipment can be determined, the diagnosis result will be given [5].
- If the fault equipment can not be diagnosed, the fault recording information is acquired, and the recording information is analyzed for further diagnosis to determine the fault equipment. The system flow of hierarchical diagnosis is shown in Figure 1 [6].

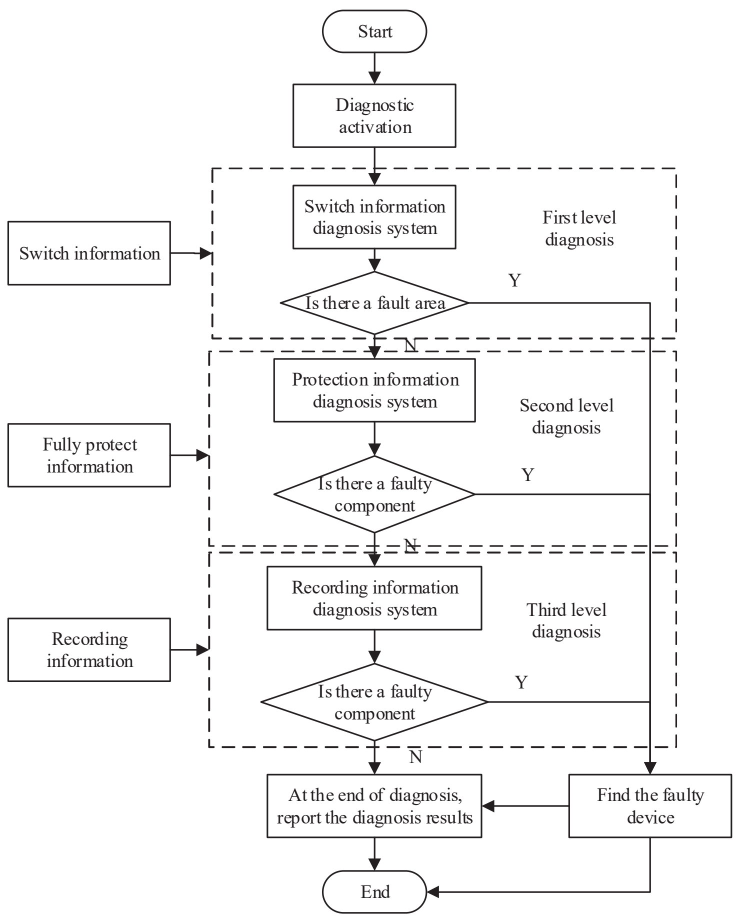

Figure 1 Hierarchical information fault diagnosis method flow of power system.

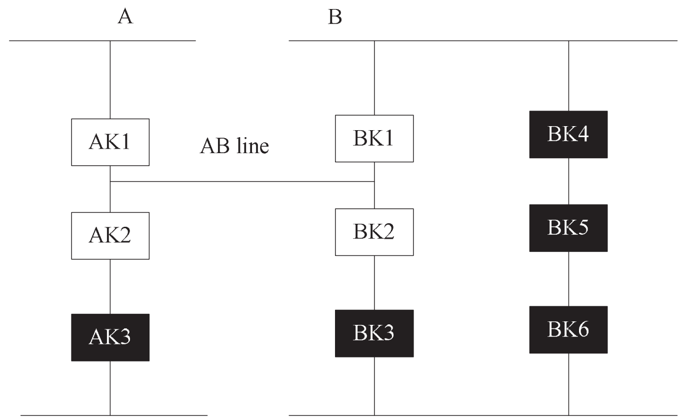

Figure 2 Fault of AB line.

2.1 Fault Area Identification Based on Switch Information

After the fault occurs, the information of switch displacement first reaches the SCADA system (data acquisition and monitoring control system), so it is the most convenient to use the information of switch displacement for fault identification. All faults of power system are isolated from the fault area by switches. On the premise that the switch information acts correctly, the outage area can be obtained by using the network topology analysis function. Without considering the switch and protection failure/misoperation, the equipment in the outage area is the fault equipment [7]. As shown in Figure 2, when the AB line fails, the switches AK1, ak2, BK1 and BK2 will trip respectively when the protection and switch act correctly, isolating the AB line from the power grid. According to the network topology with switch displacement information, it can be concluded that the component in the outage area is AB line, then AB line is the fault component.

2.2 Using Protection Action Information to Locate Fault Power Equipment

If a single switch refuses to operate or two devices with long distance fail at the same time, the faulty components can be identified by using the above information. However, for two devices with electrical distance adjacent to each other to have faults at the same time or almost at the same time, the above information can only be used to draw a possible conclusion [8]. As shown in Figure 3, if line AB and station B 1m fail at the same time, switches

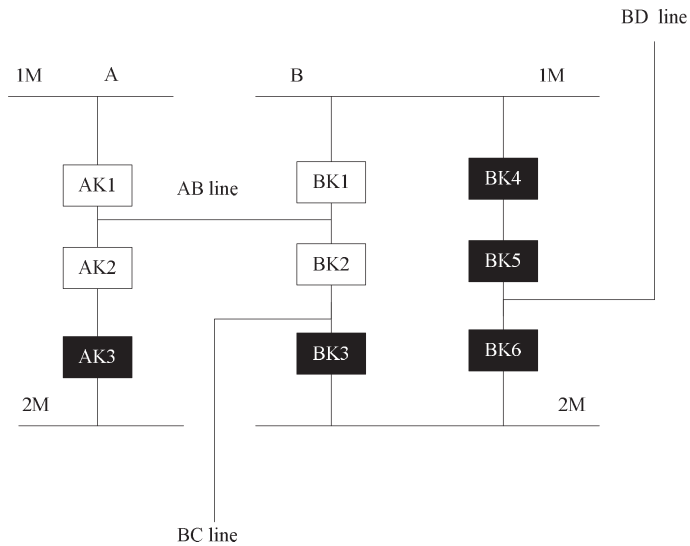

Figure 3 1M simultaneous fault of line AB and station B.

AK1, ak2, BK1, BK2 and BK4 will trip. Three possible conclusions can be drawn by using switch displacement:

- Line AB fault and station B 1m fault;
- The B line is faulty, and the BK4 switch is misoperated;
- 1m fault of station B, and the switch BK2, AK1 and AK2 are misoperated. If combined with the protection action information, the main protection action of line AB and 1M main protection action of station B are known, then the fault of line AB and 1M main protection action of station B can be judged; if the protection action information is the main protection action of line AB, then the conclusion is that the BK4 switch of line AB is maloperation; if the protection action information is 1M main protection action of station B, then the 1M fault of station B and the switch AK1, AK2 and BK2 are maloperation.

2.3 Accurate Fault Diagnosis Using Recording Information

If the fault can not be diagnosed after the above, it needs to collect the recording information for further diagnosis. At this time, the diagnosis is more difficult. This chapter uses fireworks algorithm to carry out the final accurate diagnosis of power system.

2.3.1 The origin and development of fireworks algorithm

Every festival, people will set off fireworks to celebrate, gorgeous fireworks to leave a good impression. Professor Tan Ying, in the process of watching fireworks, links the image of fireworks explosion with random search. If we can simulate the process of a fireworks explosion and constantly explore the surrounding areas, can we find an optimal fireworks value? Therefore, a new method is developed to simulate the way of fireworks explosion to search the optimal solution of multi-point explosive search problem, and named this method FWA, and gives the definition and algorithm flow of each factor of the algorithm in detail [9]. This fireworks explosion algorithm will continue to search for a new generation of fireworks until the cost of the explosion cycle is found. As a new swarm intelligence algorithm, the difference between FWA and common swarm intelligence algorithm is that FWA adopts explosive search mechanism, which is one of the important reasons for FWA's outstanding performance in search performance [10].

FWA has been widely concerned since it was proposed because of its strong solving ability. Many efforts have been made in algorithm optimization, and FWA has also been applied to many fields. In terms of algorithm improvement, the main research results include: enhanced fireworks algorithm, dynamic search fireworks algorithm, adaptive fireworks algorithm, hybrid fireworks algorithm, etc. [11]. The main application fields of fireworks algorithm are: cluster analysis, swarm robot multi-target search, non negative matrix factorization and so on.

2.3.2 Characteristics of fireworks algorithm

Fireworks algorithm as a new type of swarm intelligence algorithm, it has the characteristics and advantages of swarm intelligence algorithm. For example: intelligence, implicit parallelism, solution approximation and so on. Intelligence refers to the solution process of swarm intelligence algorithm by simulating some specific life phenomena or the change process of natural phenomena in nature. Therefore, the swarm intelligence algorithm naturally includes the characteristics of self-learning, self-organization, self-adaptive and so on [12]. In the operation process of the algorithm, individuals in the population organize to search the feasible region of the problem by themselves. According to the fitness evaluation function, the population conforms to the natural survival rule of survival of the fittest and survival of the fittest, so the algorithm is intelligent. Implicit parallelism means that in the process of evolution, individuals in a population are independent, the communication between individuals is random, and the evolution mode of each individual has nothing to do with other individuals [13]. Therefore, swarm intelligence algorithm has the characteristic of implicit parallelism. The approximation of solution means that, in many cases, the approximate solution of the optimal result is obtained by the algorithm. Swarm intelligence algorithm does not have strict mathematical theory, but uses evolutionary mechanism to guide the population to search the feasible region space. This kind of algorithm has some shortcomings, such as premature convergence or low solution accuracy. Sometimes the algorithm may not be able to find the accurate optimal solution, or it will cost a considerable performance cost to find the optimal solution. In this case, the approximate solution of the optimal solution will be used to replace the optimal solution [14].

Compared with genetic algorithm, particle swarm optimization and other swarm intelligence algorithms, fireworks algorithm also has the characteristics of explosiveness, instantaneity, simplicity, local coverage, scalability and so on. Explosiveness means that in each iteration process, fireworks produce many sparks different from themselves through explosion, some of which may be quite different from fireworks themselves. Instantaneity means that in the iterative process of the algorithm, if the sparks generated by fireworks explosion are not selected as a new species group, then these sparks will die out after the end of this iteration, that is, fireworks individuals have instantaneous existence [15]. Simplicity means that in the algorithm, the individual's ability and evolution rules are very simple, and the implementation of the algorithm is relatively difficult. Local coverage refers to the fireworks in the explosion process, which is limited by the explosion amplitude. The sparks generated by it are randomly covered in the explosion amplitude, and will not fall in the area outside the explosion amplitude, and its explosion amplitude is only a small part of the whole solution space, so the explosion has locality. Scalability refers to that there is basically no direct information exchange between individuals in the population, and the independence of individuals is high [16]. Therefore, when the number of individuals in the system changes, the impact on the whole system is small, so that the system has good scalability.

2.3.3 The principle of fireworks algorithm

Fireworks explosions produce a lot of new sparks and spray for the adjacent area. The fireworks algorithm extracts several important factors in the process of fireworks explosion, namely: initial fireworks, explosion sparks, number of sparks, explosion amplitude, etc. Through abstract design, the fireworks algorithm is established [17]. Therefore, the basic idea of the fireworks algorithm is to generate the initial population randomly in the feasible region of the problem, and then calculate the fitness value of each individual, the number of explosion sparks and the explosion amplitude, and then the explosion generates new sparks. In order to maintain the diversity of individual population, the algorithm also introduces the mutation step, that is, after completing the fireworks explosion process, select the appropriate individual from all the current individuals for mutation [18]. Finally, the fitness of the population is calculated, a batch of fireworks is selected to enter the next generation, and the iteration cycle is carried out until the optimal fireworks are found. For the convenience of narration, if there is no special explanation in the article, fireworks represent the current generation of fireworks used for explosions, and spark refers to the new spark or Gauss variation spark generated by explosion.

2.3.4 Basic flow of fireworks algorithm fault diagnosis

Step 1: initialize Z fireworks x_i (fault type) randomly in the solution space.

Step 2: set $i = 1$, the maximum number of iterations is T, evaluate the fitness value $f(x_i)$ of the current fireworks x_i, calculate the explosion radius R_i and the number of explosion sparks S_i [19].

Step 3: generate explosion spark according to formula (1), (2), (3).

$$R_i = a \times \frac{f(x_i) - y_{\min} + c}{\sum_{i=1}^{N}(f(x_i) - y_{\min}) + c} \tag{1}$$

$$S_i = b \times \frac{y_{\max} - f(x_i) + c}{\sum_{i=1}^{N}(y_{\max} - f(x_i)) + c} \tag{2}$$

$$S_i = \begin{cases} \text{round } (p * b), & S_i < pb \\ \text{round } (q^* b), & S_i > qb,\ p < q < 1 \\ \text{round}(S_i), & \textit{other conditions} \end{cases} \tag{3}$$

In the formula, a and b are constants, a is used to control the size of the explosion radius, b is used to control the number of explosion sparks; c is used to prevent molecules or denominators from being zero, which leads to meaningless formula; $f(x)$ is the problem to be solved; p and q are constants; $\text{round}(\ )$ is the rounding function, and the rounding principle is rounding [20].

Step 4: generate variation sparks.

Step 5: execute mapping rules for newly generated explosion sparks and mutation sparks.

Step 6: select the next generation spark among the fireworks x_i, explosion spark and variation spark candidates, $i = i + 1$.

Step 7: repeat steps 2 to 6 until $i = T$, output the optimization result and get the diagnosis result.

3 Simulation Experiment

This research is in the Windows 10 environment, using MATLAB 201 5b to develop, database adopts MySQL software, both of which are open source, which is convenient for programmers to develop.

3.1 Examples

Taking the 36 node wiring diagram of Electric Power Research Institute as the model, the simulation analysis is carried out. The network wiring diagram of the simulation system is shown in Figure 4.

The power grid is divided into four parts, one main station and four sub stations (central station). Suppose that the left part bounded by lines 6, 7 and

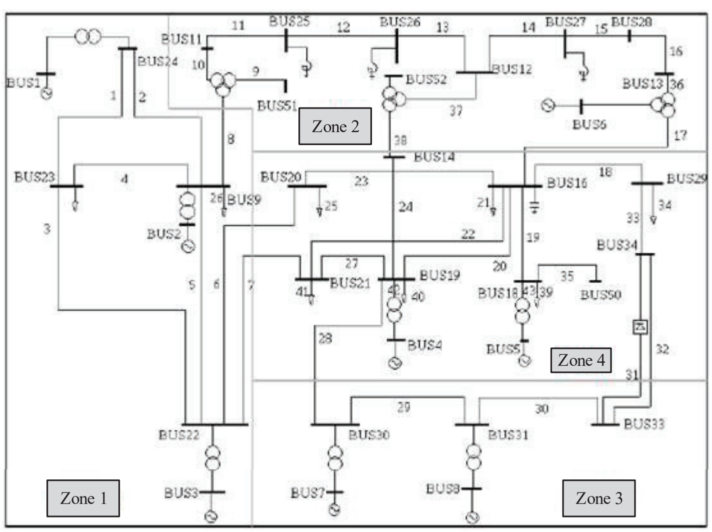

Figure 4 Network wiring diagram of simulation system.

8 is area 1, with No. 1 sub station; the upper part bounded by lines 8, 17 and 38 is area 2, with No. 2 sub station; the lower part bounded by lines 28, 31 and 32 is area 3, with No. 3 sub station; the rest of the middle part is area 4, with No. 4 sub station. Each sub station can communicate with the master station, and also exchange information between the sub stations, so as to achieve information sharing, increase the reliability of diagnosis and improve the speed of diagnosis.

3.2 Parameter Setting

The number of initial individuals formed in the fireworks algorithm is the number of devices contained in the fault area. The parameter settings of the fireworks algorithm are shown in Table 1 below.

Table 1 Parameter setting of fireworks algorithm

Name	Parameter
Maximum number of iterations	200
Number of fireworks	100
First Gaussian coefficient	0.3
Number of explosions	6
Explosion radius	5
Variation spark number	5
Explosion limit A	0.3
Explosion limit B	0.6

3.3 Analysis Tools

Power System Analysis Software Package (PSASP) is a set of powerful power system analysis program developed by China Electric Power Research Institute. It has the advantages of stable operation, accurate calculation results, convenient use and friendly interface. It is a commonly used software for power system calculation and simulation in China, and its results are generally accepted by everyone.

The development of PSASP began in 1973. For many years, in order to meet the needs of the rapid development of China's power system, PSASP has continuously increased the expansion function. Now PSASP includes more than ten kinds of calculation programs, such as power flow, transient stability, small signal stability and so on, involving various analysis methods, such as steady-state, transient, linear, nonlinear, optimization and so on. At the same time, it keeps tracking new computer technology, and makes it develop into a software package with friendly interface, scientific structure, resource sharing, highly integrated and open.

PSASP is an important tool for power system planners to determine economic and reasonable and technically feasible planning and design plans; it is an effective means for operation dispatcher to determine the operation mode of the system, analyze system accidents and seek anti accident measures; it is a powerful assistant for scientific researchers to study new problems such as new equipment and new component input system; it is a software facility for teaching and research in colleges and universities.

3.4 The Analysis Results of An Example

Example 1: line 15 has three-phase short circuit fault. If the main protection circuit breaker on the left side of line 15 refuses to operate, the backup protection of line 15, that is, the circuit breaker on the left side of line 14 and the circuit breaker on the right side of line 15, will act to remove the fault. The fault is limited in zone 2. Because of the circuit breaker refusing to operate, the switch status information uploaded by the protection in substation 2 can quickly diagnose the fault. The fault zone includes line 14, 15 and busbar 27. It is not possible to determine which equipment has fault. No.2 sub station uploads the diagnosis information to the master station, and the master station converts the state vector s: in the genetic algorithm into three dimensions according to the information. Assuming that the fault current in positive direction flows through lines 14, 15 and busbar 27 when the power supply is on the left side of line 14, the diagnosis result is $S_n = (0, 1, 0)$, that is line 15 fault. When the right side of line 15 is assumed as the power supply, the diagnosis result is $S_n = (0, 1, 0)$, which is the same as the previous assumption. So the final diagnosis result is line 15 fault.

Example 2: short circuit fault between line 5 and busbar 22. The final fault area diagnosis includes line 3, 5, 6, 7, 25, busbar 22, 20, and the main station takes s: as 7 dimensions. Take the upper end of line 3, the lower side of busbar 22, the upper end of line 5, the upper side of busbar 20, the end of line 25 and the right end of line 7 as the hypothetical power supply to carry out the pyrotechnic explosion operation. The diagnosis results were as follows:

Upper end of line 3: $S_n = (0, 1, 0, 0, 0, 0, 1)$;
Lower side of busbar 22: $S_n = (0, 1, 0, 0, 0, 0, 1)$;

Upper end of line 5: $S_n = (0, 0, 0, 0, 0, 0, 1)$;
Upper side of busbar 20: $S_n = (0, 0, 0, 0, 0, 0, 1)$;
At the end of line 25: $S_n = (0, 0, 0, 0, 0, 0, 0)$;
Right end of line 7: $S_n = (0, 1, 0, 0, 0, 0, 1)$;

The final diagnosis results are line 5 and busbar 22 fault, and the diagnosis results are consistent with the actual fault.

Example 3: a three-phase short circuit fault occurred in the connecting line of zone 1 and zone 4, that is, the end of line 7 near busbar 22. If the circuit breakers do not refuse to operate or misoperate, the fault of line 7 can be diagnosed by substation 1 according to the protection information, and the fault of line 7 can also be diagnosed by substation 3. The sub station 1 communicates with the sub station 3, calls the diagnosis result of the sub station 3, and finally determines that the line 7 fault is a simple fault, and the diagnosis result is uploaded to the master station.

4 Conclusion

To sum up, with the development of the power systems, power grid fault diagnosis is more and more important to ensure the security and stability of the power system. According to the current situation and existing problems of power system fault diagnosis, this paper proposes a hierarchical distributed fault diagnosis method for power system. That is: the information of the scheduling end is layered, and the plant station sets up a sub station system to form a distributed system; the organic combination of layered and distributed can achieve the maximum resource utilization, and improve the reliability of fault diagnosis results; combined with fireworks algorithm, the switch information is used to form a fault area, reduce the size of the search space, and improve the search efficiency. This paper also puts forward the technical guarantee for real-time fault diagnosis, and configures the substation system.

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Biography

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