

Intelligent Operation and Maintenance of Micro-grid Technology and System Development

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Abstract. In order to achieve the micro-grid operation and management, Studying the micro-grid operation and maintenance knowledge base. Based on the advanced Petri net theory, the fault diagnosis model of micro-grid is established, and the intelligent diagnosis and analysis method of micro-grid fault is put forward. Based on the technology, the functional system and architecture of the intelligent operation and maintenance system of micro-grid are studied, and the microcomputer fault diagnosis function is introduced in detail. Finally, the system is deployed based on the micro-grid of a park, and the micro-grid fault diagnosis and analysis is carried out based on the micro-grid operation. The system operation and maintenance function interface is displayed, which verifies the correctness and reliability of the system.

1. Introduction

At present, domestic and international micro-grid operation and management usually focus on monitoring and energy management. Due to the fact that micro-grid has many micro power sources, diverse output characteristics, complex network structure, it is more prone to malfunction. The problems of power quality, immature micro-grid protection and control technology, low reliability of micro-grid operation and high requirement of professional knowledge of maintenance personnel are becoming increasingly prominent.

When the grid accident occurs, the relay protection system will quickly detect the fault symptoms, and issue instructions to the relevant protection device, in order to jump off the circuit breaker, thus isolating the fault. The task of fault diagnosis is to use the alarm information received by the scheduling control center to determine the faulty components. In the large number of alarm information received by the dispatch control center, there may be many uncertain factors such as protection malfunction, loss of information transmission or distortion. For microgrids, the fault analysis process is similar to large power grid. Due to the addition of distributed power supply, the microgrid's own operating characteristics are more complex. In such cases, it is very difficult for the staff to quickly read and understand the substance of the original alarm information without any processing and to correctly determine the faulty element.

In order to solve this problem, this paper studies the micro-grid operation and maintenance knowledge base. Based on the advanced Petri net theory, the fault diagnosis model of micro-grid is established, and the intelligent fault diagnosis and analysis method of micro-grid is put forward. On the basis of studying the integrated access technology of microgrid information and communication



technology, the functional system and architecture of intelligent operation and maintenance system of microgrid are studied, and the micro-grid fault diagnosis function is introduced in detail. Based on the deployment of micro-grid system in a park, we have carried out fault diagnosis and analysis of the operation, thus verifying the correctness and reliability of the system.

2. Micro - grid intelligent operation and maintenance technology

2.1. Operation and maintenance knowledge base

Micro-grid intelligent operation and maintenance knowledge base contains micro-grid fault handling, equipment and system maintenance knowledge. The micro-grid intelligent operation and maintenance knowledge base is based on the experience rules of micro-grid experts and first-line operation and maintenance personnel, analyzes the operation data of micro-grids, extracts micro-grid fault data; lists the fault phenomena of micro-grid, studies the corresponding fault isolation and fault recovery methods; statistics micro-grid system and equipment failure number, failure rate, change situation; structures micro-grid intelligent operation and maintenance knowledge.

Knowledge base through a comprehensive and organized knowledge management to form a knowledge cluster of facts, association rules and concepts. It is the oretical basis of equipment operation and maintenance, and it is also an important basis of intelligent decision-making.

The operation and maintenance knowledge base system structure diagram is shown in Figure 1.

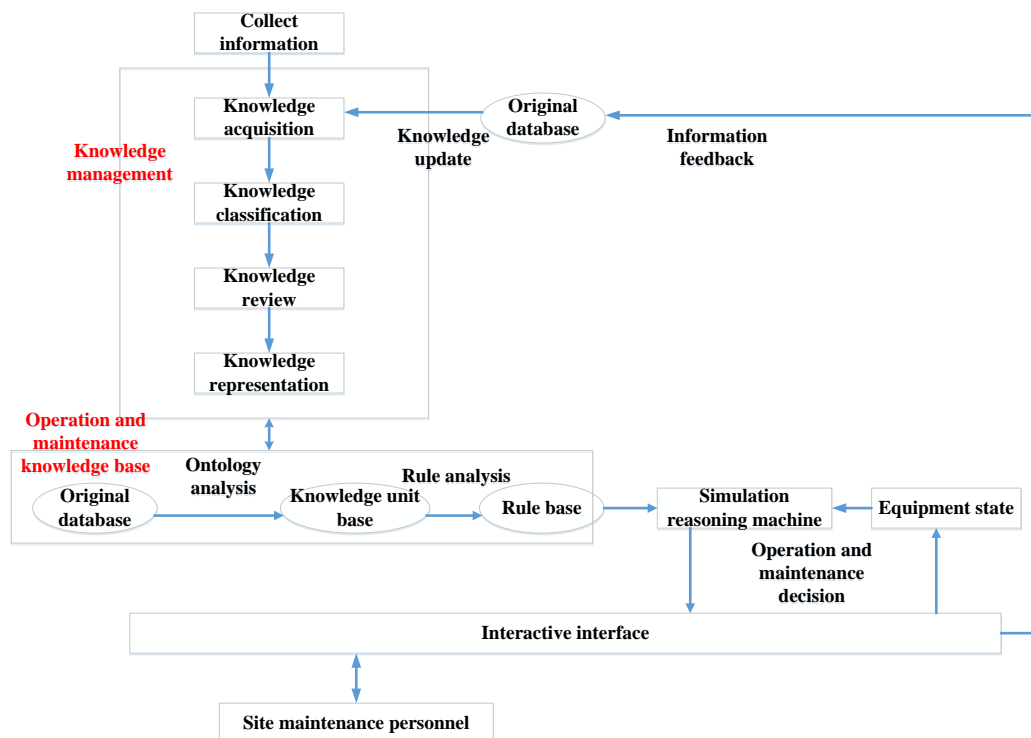


Fig 1. Operation and maintenance knowledge base system structure diagram

In the figure, the original database is used to store the initial state and the original reasoning of the application environment of the micro-grid. At the same times, the original database is used to store the temporary results and information generated during the reasoning process. So the original database is in a constantly updated state. The rule base is the heart of the knowledge base model and contains all the transformation rules needed to convert the problem from the initial state to the target state. The inference engine consists of a set of programs that use the rules in the rule base and the data in the database to

reason and explain the reasoning. The process of self-construction of knowledge base is also the process of micro-grid intelligent operation and maintenance system.

2.2. Intelligent fault diagnosis method

2.2.1 Micro-grid fault diagnosis method based on Petri nets. The main difference between micro-grid and large power grid is that the operation mode of micro-grid is flexible and the topology is diversified. Based on this, the advantages of each artificial intelligence theory are combined. The coloured Petri theory is applied to the micro-grid fault diagnosis. The information is encapsulated into the database by using the object-oriented idea, which enhances the versatility of the micro-grid fault diagnosis model and enhances the fault tolerance of the model.

2.2.2 Advanced Petri net definition. Petri net is a system model that can be represented by a mesh pattern, including two nodes: state (condition) and event. The Token distribution that represents the state information is added to the directed graph where the condition is a node. Events trigger rules that cause events to ignite and cause state evolution to describe the dynamic and static state of the system. The following is a brief introduction to the basic concepts of Petri nets.

The structure of a Petri net includes three basic elements: place, transition, and arc. Place (location): Represents the element node of a state. The place not only represents a place, but also represents the state of the system through a certain resource stored in it, also called P element. The resources stored in the place are called Token. The Petri net represents the different states of the system through the number of Token inside the place. The limit on the amount of storage resources in the place is called the capacity of the place.

The graphical representation of the Petri net is the representation of the place node, the transition node, and the directional arc. In the graph, "○" is used to represent the place node, "┆" (or "□") is used to represent the transition node. The ordered arc (x, y) is represented by a directed arc (pointing to the arrow) from X to Y. If the directed arc is directed from the transition to the place, then the place is an output place of the transition, the transition is an input transition of the place. On the contrary, if the directed arc is directed from the place to the transition, then the place is an input place of the transition, the transition is an output transition of the place. If $N1=(S1,T1,F1)$, place collection $S1=(s1, s2,s3, s4, s5, s6,s7)$, transition collection $T1=(t1,t2,t3,t4)$, flow relation $F1=\{(s1,t1), (t1,s2), (s2,t2), (s4, t2), (s3, t3), (t3, s4), (s4, t2), (t2, s5), (s5, t4), (t4,s6), (t4,s7)\}$. The graphical representation of Petri net N1 is shown in Figure 2.

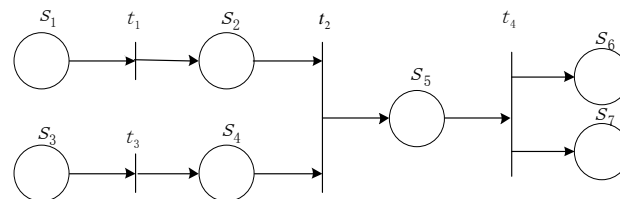


Fig 2. The graphical representation of Petri net N1

2.2.3 Fault diagnosis of micro-grid based on advanced Petri net. The micro-grid fault diagnosis model based on advanced Petri net is shown in Figure 3:

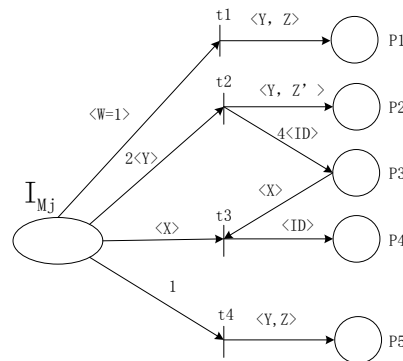


Fig 3. Fault diagnosis of micro-grid based on advanced Petri net

In the micro-grid fault diagnosis model based on advanced Petri net, Token coloring, transition and place meanings are shown in the following table.

The ignition rules of each transition in the diagnosis model are:

Transition t1: In the input place IMj, there is a Token with an identity value of 1 corresponding to the membership color, transition t1 ignition, to the transient fault diagnosis results place P1 output the corresponding accuracy rate of fault element and fault diagnosis .

Transition t2: In the input place Imj, there are two Token with the same component color, transition t2 ignition, after the corresponding fuzzy operation \oplus ($\oplus : A \oplus B = C$, where the matrix A, B, and C are matrices with the same number of rows and the same number of columns. and $C_{ij} = \min(A_{ij}, B_{ij})$), to the match fault diagnosis results place P2 output the corresponding accuracy rate of fault element and fault diagnosis . At the same time, output a number of redundant tokens to P3. The number is set according to the number of single protection maximum protection elements -1 to ensure that the transition t3 is ignited.

Transition t3: When the input place IMj and the redundant message store contains the same protection of the Token, transition t3 ignition, to the redundant message recovery station place P4 output Token, and clear the redundant Token in the place P3 and P4.

Transition t4: When the input place Imj contains the Token with a lifetime color value of zero , transition t4 ignition, to the delay fault diagnosis results place P5 output the corresponding accuracy rate of fault element and fault diagnosis .

Table 1. The meaning of Token ,color and place

element	meaning
X	Protective coloration
Y	Protected component color
Z	Membership color
W	Survival color
t1	Transient fault diagnosis transition
t2	Matching fault diagnosis transition
t3	Redundant messages empty transition
t4	Delay fault diagnosis transition
P1	Transient fault diagnosis results place
P2	Matching fault diagnosis results place
P3	Redundant messages place
P4	Redundant messages recycle bin place
P5	Delay fault diagnosis result place

Based on the micro-grid fault diagnosis model of the advanced Petri net , through the logical reasoning of information, eventually get faulty components. The fault diagnosis system queries through the component location table, find the corresponding location record. The faulty component and the fault location information are displayed on the screen so that the operator can process the accident. The fault diagnosis model is applicable to the fault diagnosis of any topology micro-grid, which is very versatile.

The process of microgrid fault diagnosis based on Petri method is shown in Figure 4.

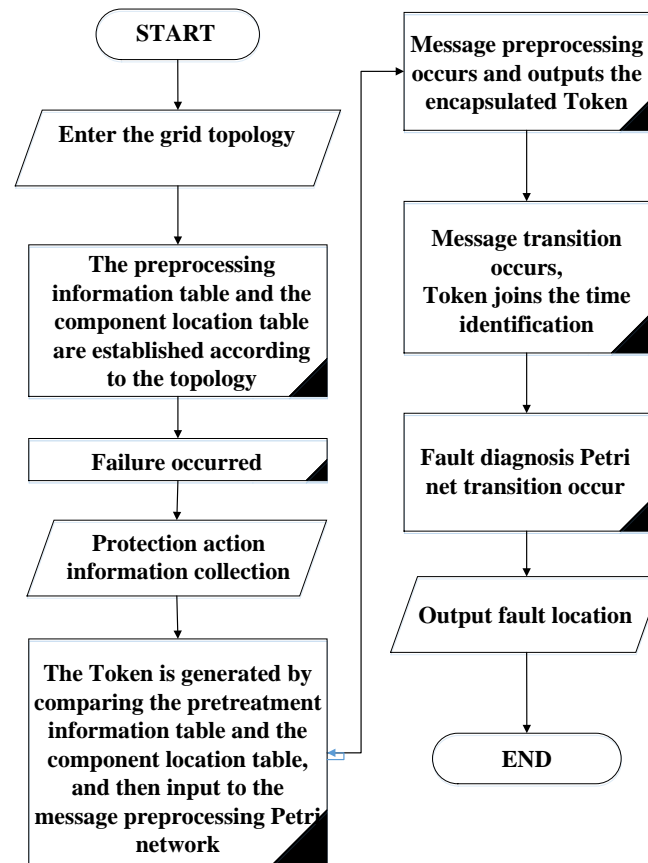


Fig 4. Micro-grid fault diagnosis process

After the fault element is determined, the fault mode can be determined by analyzing the fault element status and constructing the corresponding component Petri net model.

3. Micro - grid intelligent operation and maintenance system

Micro-grid intelligent operation and maintenance system functions shown in Figure 5, including distributed power, energy storage data acquisition and processing based support functions, and comprehensive evaluation and analysis, distributed power generation power forecasting, load forecasting, knowledge base query, remote maintenance , Micro-grid fault diagnosis and processing and other advanced applications.

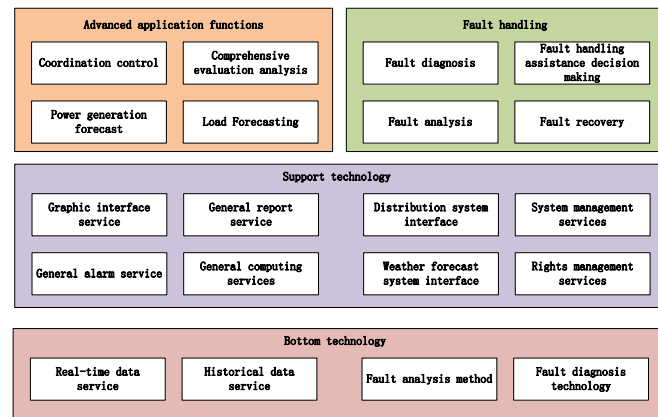


Fig 5. Micro-grid intelligent operation and maintenance system functions

Micro-grid intelligent operation and maintenance system using service-oriented architecture (SOA) design, according to the function, including pre-service, SCADA system, advanced application subsystem. It consists of database server, application server, communication gateway machine, remote workstations, maintenance workstations, switches and other equipment.

The system structure is shown in Figure 6:

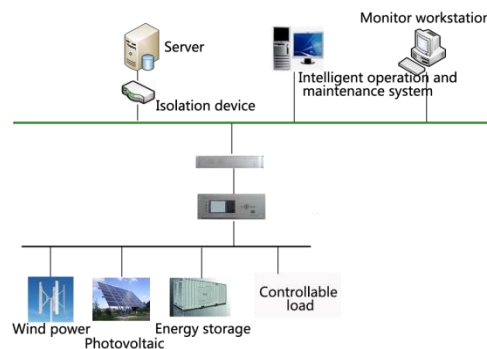


Fig 6. Micro - grid intelligent operation and maintenance system architecture diagram

The establishment of the logical structure of the system will make the maintenance resources of the system more organically combined to ensure the smooth operation of the entire system diagnosis and maintenance process. From the knowledge management, database management, diagnosis and maintenance of three aspects, establish a system logic structure with information sharing and system diagnosis, maintenance and other information interaction, enhance the diagnostic maintenance capability of the system.

The detailed structure is shown in Figure 7.

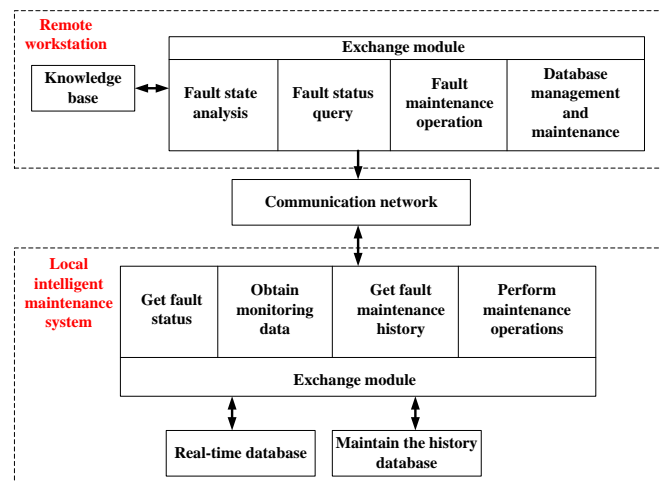


Fig 7. Logical structure of intelligent operation and maintenance

The main components of the structure are as follows:

- 1) Core diagnostic resources: maintenance experts, knowledge base, maintenance of historical database, system status information database, monitoring image database.
- 2) Interface layer: interface with maintenance personnel, system status information interface, maintenance service information output interface and so on.
- 3) Support environment layer: communication network and database. Knowledge base is the core knowledge source of remote maintenance. It includes two sub libraries: maintenance of knowledge base and fault diagnosis knowledge base. The data base and data of microgrid system design, manufacture, installation and debugging are stored in the maintenance repository. The fault diagnosis knowledge base stores the accumulated diagnosis and maintenance knowledge. With the continuous increase of maintenance services, the knowledge base will provide more powerful ability for intelligent diagnosis service.

The site maintenance personnel access the maintenance history database, the system status information database, the monitoring image database through the interface layer. The interface layer is provided by the maintenance server. Through the information exchange to get the technical support of remote maintenance experts, so that the site maintenance personnel can quickly and efficiently solve the system hardware failure.

4. Application examples and system display

4.1. Example analysis

Figure 8 shows the topology of a park microgrid system. There are 15 lines in the figure, respectively equipped with current quick-break protection, over-current protection, vertical differential protection, the direction of the vertical protection.

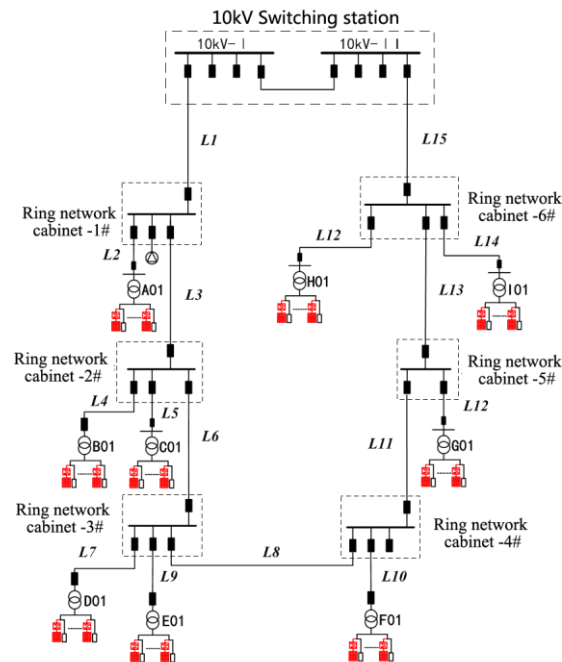


Fig 8. Micro - grid topology of a park

Multiple faults occur simultaneously in microgrid system: Line L3 is close to the system side overcurrent protection action. Line L3 is close to the PV side current quick-break protection action. Line L5 on the differential protection action. Line L15 is close to the system side current quick-break protection action. The protection configuration on the faulty line is shown in Table 2:

Table 2. Fault line protection configuration

Protection installation location	Protection type	Protection element
Line L3 close to the system side	Current quick-break protection	L3
Line L3 close to the system	Overcurrent protection	L3,L4,L5,L6
Line L3 close to the PV	Current quick-break protection	L3
Line L3 close to the PV	Overcurrent protection	L1,L2,L3
Line L5	Longitudinal differential protection	L5
Line L6 close to the PV	Overcurrent protection	L3,L4,L5,L6
Line L15 close to the system side	Current quick-break protection	L15
Line L15 close to the PV	Current quick-break protection	L15
Line L15 close to the PV	Overcurrent protection	L15

Message preprocessing the Petri net receives four protection action messages:

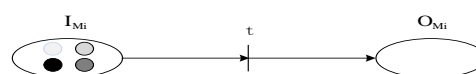


Fig 9. Message preprocessing Petri net initial identification

Create a component location table. Element_Location contains two elements: Electronic_element, Location. As shown in Table 3.

Table 3. Element_Location

Electric_ele	Location
L3	1_2
L5	C01_2
L15	5_6

Create a preprocessing information table. The protection information (Protection_ID), the protected element information (Electric_element), and the membership degree (Memship_value) are stored in the pre-processing information table (Pretreatment_table). Transition t ignition. Read the corresponding 5 records from the database as shown in Table 4:

Table 4. Message preprocessing record

Protection_I	Electric_ele	Memship_va
R_L3_1_OC	L3	0.9
R_L3_1_OC	L5	0.8
R_L3_2_IO	L3	0.95
R_L5_0_Diff	L5	1
R_L15_1_IO	L15	0.95

In the table, The attribute Protection_ID column R represents protection, L represents location, 0 represents pilot protection, 1 represents near power side, 2 represents near the photovoltaic side, IOC represents current quick-break protection, OC represents over-current protection, Diff represents vertical differential protection, Dir represents the direction of the vertical protection.

Transition t ignition, through the encapsulation of the 5 records (contains protected color, protected element color, membership color), the message preprocessing Petri network identifier is obtained. As shown in Figure 10.

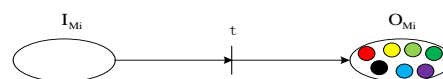


Fig 10. Message preprocessing Petri network identifier

After message preprocessing, the token of the Petri network is passed into the message passing Petri network through the place OMi. Each token is equivalent to a four dimensional vector. The processed token enters the fault diagnosis Petri network, and the initial state identification of the fault diagnosis Petri network is shown in Figure 11.

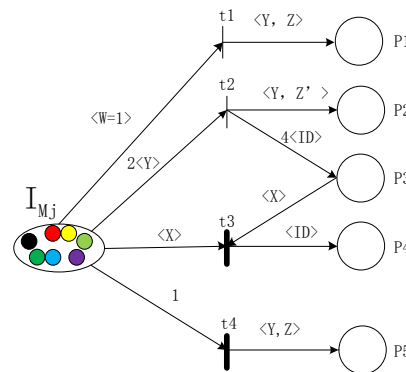


Fig 11. Initial state identification of fault diagnosis Petri nets

In the fault diagnosis Petri nets, the transient fault diagnosis transition condition is satisfied. After enough time delay, the lifetime of each token ends. Delayed fault diagnosis transition meet the conditions. Transition t1 ignition. The resulting status is shown in Figure 12.

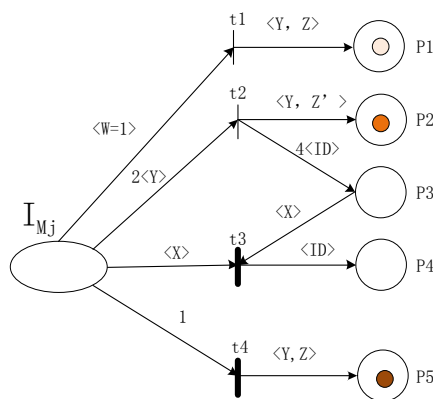


Fig 12. The final status of the fault diagnosis Petri net

Finally, the fault diagnosis system output fault components: L3 (accuracy of 0.95), L5 (accuracy of 1), L15 (accuracy of 0.95).

According to the output of the fault component query component location table, you can get the corresponding fault location:

L3 (accuracy rate is 0.95): between 1# ring net cabinet and 2# ring net cabinet;

L5 (accuracy rate of 1): between C01 box change and 2# ring network cabinet;

This method can effectively diagnose the fault location. To a certain extent, we get rid of the traditional Petri network method of re constructing the Petri network according to the topology. It is necessary to build the table of element location according to the topology.

4.2. System display

The micro-grid intelligent operation and maintenance system consists of on-site maintenance personnel, maintenance server and remote maintenance center. The system information model reflects the information relationship between the main functions of the system. Through the sharing of resources, mutual cooperation and mutual support to effectively organize. Mobilize maintenance resources within the system to provide support for system maintenance. The system includes a monitoring function module, an operation module and a production management module. The monitoring function module can realize the precise monitoring of microgrid. The operation module analyzes the various indexes of

microgrid operation, including: comprehensive evaluation, report management, intelligent analysis, operation and maintenance analysis, asset management and system management. Production management module to guide micro-grid operation and maintenance personnel to carry out various management, including a variety of report statistics, defect statistics, fault records, spare parts management.

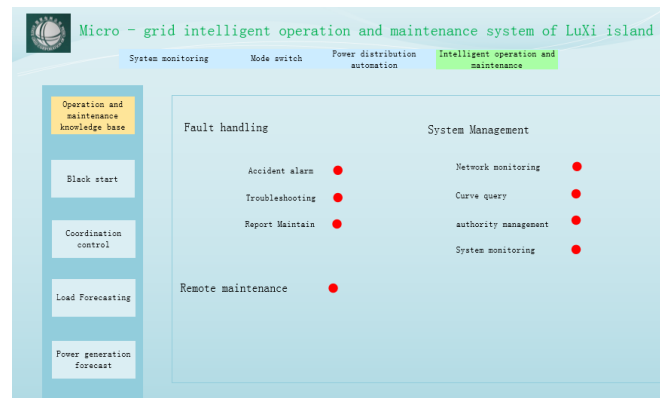


Fig 13. Intelligent operation and maintenance interface

The fault diagnosis knowledge base combines the experience rules of the micro-grid experts and the first-line operation and maintenance personnel, analyzes the micro-grid operation data and extracts the microgrid fault data. It lists micro-grid fault phenomena. It studies the corresponding fault isolation and fault recovery methods. It counts the number of failures, failure rates and changes in microgrid systems and equipment. It structures micro-grid intelligent operation and maintenance knowledge. Micro-grid intelligent operation and maintenance knowledge base is based on micro-grid intelligent operation and maintenance system structures.

station name	interval	application type	tele-signalling value	tele-signalling state	protection settings	alarm information
10kV public interval	SCADA	separate	normal			
10kV public interval	SCADA	shut	normal			
10kV public interval	SCADA	shut	normal			

Fig 14. Fault protection information display

pre-sign	protected original	accuracy
10kV	sv1	0.99999
10kV	sv2	0.99999
10kV	sv3	0.99999
10kV	sv4	0.99999
10kV	sv5	0.99999

Fig 15. Fault preprocessing information display

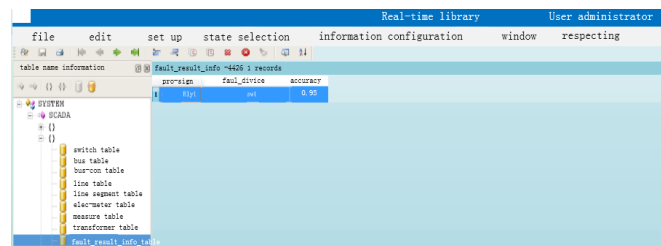


Fig 16. Fault diagnosis result information display

5. Concluding Remarks

There are many micro-power in the micro-grid. Diversified output characteristics, complex networking structure, makes the system more prone to failure. The application of power electronics in micro-grid has the following problems: power quality problems, micro-grid protection and control technology is immature, investment and operation and maintenance costs are high. So it is extremely important to study the operation and maintenance of micro-grid.

Based on a park microgrid, an example is deployed to the system. Based on the operation of the microgrid, the fault diagnosis and analysis of the microgrid system are carried out to verify the correctness and reliability of the system. At present, the system is running well, micro-grid operation and maintenance knowledge base needs field operation personnel through long-term operation and maintenance experience to improve, in order to improve the system operation and maintenance reliability, in order to better adapt to micro-grid operation and maintenance needs.

Acknowledgments

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