Fault management technology of power communication room based on the Internet of Things technology

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Abstract. With the continuous development of society, the construction of smart grids has gradually begun to be valued. Smart grids can liberate more labor and enable managers to manage the grid quickly and easily. The power communication network occupies an irreplaceable position in the smart grid. However, it is inevitable that various equipment failures will occur. Therefore, it is necessary to advance the time of fault handling through fault management, then reduce the fault harmfulness. In this paper, with the support of the Internet of Things technology, a monitoring system of the power communication room is constructed based on the configuration status and application environment of equipment, and an intelligent analysis method for fault location of the power communication room based on active detection is proposed. As a result, the reliable and stable operation of the power communication room can be guaranteed by using passive management and active management.

1 Introduction

Nowadays, during the continuous development of the power system, the operation reliability is continuously improved, so that the power system can better serve the people, but the occurrence of accidents in the system cannot be completely avoided, and with the interconnection of the power system, the severity of accidents is correspondingly aggravated. By improving the technical level of secondary auxiliary systems such as power system alarm processing, fault diagnosis and fault location, the hidden faults can be eliminated in the state of not occurring, and the faults can be limited to small areas, so as to reduce the harm of accidents and even avoid the occurrence of accidents. As a kind of advanced scientific technology, intelligent substation technology can significantly improve the technical level of secondary auxiliary systems [1]. Among it, the reliable transmission of information is a key part of the entire process of smart substation. Only when the information can be reliably transmitted can the control center grasp accurate information and make effective decisions. However, there are obvious obstacles to the realization of this part. As the scale of the power communication network continues to expand and the structure continues to be complicated, the failure rate and the fault harmfulness of network are on the rise. In addition, the transmission equipment in the power communication network now has the situation of multi-standard and multi-manufacturer, which adds difficulty to the control of the power communication network. Therefore, the

efficient troubleshooting and fault location in the communication room is the key to solve this problem [2].

Based on the configuration and application environment of equipment in the power communication room, this paper firstly builds a monitoring system of the power communication room, specifically describes the indicators and parameters that the power communication room needs to monitor, and then introduces the key technology for realizing monitoring automation-Internet of Things technology, which lays the foundation for the subsequent active detection. Finally, an intelligent analysis method for fault location of the communication room based on active detection is proposed to achieve accurate and rapid fault location. Under the joint action of passive monitoring and active detection, hidden faults will be discovered at an earlier stage, so that the faults can be dealt with in time, then the effect of reducing the harmfulness of the faults can be achieved.

2 Monitoring system of the power communication room

Based on the configuration and application environment of equipment in the power communication room, this chapter sets the monitoring system of the power communication room under the premise that comply with the relevant regulations of the power grid company. The specific monitoring content is divided into four modules, namely the environment monitoring module, the security monitoring module, the equipment monitoring module and the remote monitoring module [3] [4]. Among them, the remote monitoring module is to ensure that the

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content of other three modules can be remotely grasped by managers through the APP monitoring, and it removes the working environment restriction of monitoring personnel, but does not involve monitoring content expanded, so the following only design the monitoring content of the environment, security and equipment modules according to actual needs.

2.1 Environment monitoring module

The environment monitoring module can remotely control the start and stop of the air conditioner by detecting the environment indexes such as temperature and humidity in the power communication room. The monitoring server is connected to the environmental monitoring equipment through the network interface to realize the monitoring of the environment [5]. The specific monitoring content is shown in Table 1.

Table 1. Monitoring content of the environment monitoring module

Telemetering	Environmental temperature and humidity
	Cabinet temperature and humidity
	Cable temperature
Teleindication	Indoor and outdoor air pressure
	Abnormal temperature and humidity
	Abnormal hydrogen concentration in the battery
	Air conditioning working condition
Telecommand	Cabinet latch condition
	Turn on/off air conditioner
	Turn on/off lighting

2.2 Security monitoring module

The security monitoring module realizes the video

monitoring, personnel access monitoring and illegal intrusion monitoring through the monitoring camera and access control system of the power communication room. The specific monitoring content is shown in Table 2.

Table 2. Monitoring content of the security monitoring module

	Access control	Video monitoring
Telemetering	Credit card record	Monitoring time
	Alarm record	Local video storage capacity
	Opening door record	
Teleindication	Door condition	Video monitoring equipment condition
		Monitoring object alarm Linkage alarm
Telecommand	Turn on/off door	Set up camera equipment
	Rights management	Set up screen Splitter
		Set up matrix Switcher
		Set up video Switcher

2.3 Equipment monitoring module

The monitoring of the equipment monitoring module includes power supply, DC, UPS, switches, etc. In this module, the IOT technology is used to identify the status of power supply, DC and UPS, fault state, and the port fault status are identified through the switch command, the equipment running status are monitored through the cabinet temperature, finally the status of the main equipment are summarized, and the equipment faults are detected in time through the remote online monitoring, then the maintenance time is shorten [6]. The specific monitoring content is shown in Table 3.

Table 3. Monitoring content of the equipment monitoring module

	Telemetering	Teleindication	Telecommand
Automatic Transfer Switching (ATS)	voltage	Current use loop	Use loop switching
	Current	Automatic/Manual Fault alarm	Automatic/manual switching
	Frequency	Abnormal voltage and current	
AC Distribution Panel	Voltage	Switch state	Turn on/off switch
	Current	Abnormal voltage and current	
	Frequency	Switch fault	
	Power factor	Lightning protection device fault	
High Frequency Switching Power Supply	Voltage	Module running state	boost/floating charge
	Current		Rights management
	Temperature		Set boost/floating charge pressure
	Module current limiting value	Fault alarm	Component parameter setting
DC Distribution Panel	Voltage	Switch state	Turn on/off switch
	Current	Abnormal voltage and current	
	Cable temperature	Switch fault	
		Lightning protection device fault	
Integrated DC-DC Power Supply	Output voltage	Abnormal output voltage and current	
		Output switch fault	
	Output current	Lightning protection device fault	
Uninterruptible Power Supply (UPS)	Voltage	Sync/out of sync	
	Current	UPS/ Bypass power supply	
	Frequency	Abnormal battery discharge voltage	
	Battery temperature	Equipment fault	

Inverter	Voltage Current Frequency	Abnormal voltage Abnormal current Abnormal frequency
Lead Acid Battery	Capacity Voltage Current Battery temperature	Charge/discharge Abnormal voltage Abnormal current Abnormal battery temperature

3 Internet of Things technology in the power communication room

The Internet of Things (IOT) is a network to realize intelligent identification, positioning, tracking, monitoring and management by connecting any item to the Internet according to agreed protocols through information sensing equipment such as RFID, infrared sensors, global positioning system, laser scanner and so on. In terms of its essence, it is still the Internet that we are familiar with, except that the participating objects are no longer groups composed only of people, and the objects also participate in them, thus it has the functions of real-time tracking and positioning, real-time data collection, etc [7]. The Internet of Things has a three-layer structure, from the bottom to the top: the perception layer, the network layer and the application layer [8]. The lower layer serves as the basis of the upper layer, which in turn realizes the functions of collecting data, transmitting data and processing data. The traditional Internet of Things technology can collect data, and issue alarms after data processing to remind managers to take corresponding measures. However, there is a problem when it is used in the power communication room. Passively waiting for the alarm information is not a good measure to deal with failures, because the time left for the management personnel to deal with the fault after receiving the alarm information is not enough, we can take active detection to find the fault, so as to weaken the fault at an earlier stage. In order to achieve this function, a signal transmitter and a signal receiver can be added to the traditional sensor to realize the functions of sending a detection signal and receiving a detection signal, then transmit the data back to the control center through the traditional signal transmission channel of the Internet of Things, finally, on the basis of these data, the management personnel locate the fault and take countermeasures at an earlier stage.

In the application of the Internet of Things in the power communication room, the reliability and integrity of the data are the key to ensuring the effectiveness of the subsequent management work, so stable data transmission is particularly critical. In addition, a variety of sensors are used in the power communication room, correspondingly, various types of data need to be transmitted, so that there is a problem of mutual data interference. Therefore, a transmission method that can stably transmit data and can effectively avoid mutual influence among data is required [9]. The multi-carrier aggregation transmission technology is adopted in the power communication room, which is an orthogonal frequency division multiplexing technology, it can divide the channel into multiple orthogonal channels, and can

decompose a high-speed data into low-speed parallel data, then modulates these data onto the channel to achieve information transmission. Orthogonal signals can be separated at the receiving end to avoid mutual interference among the various channels. Since the channel-related bandwidth is greater than the signal transmission bandwidth of the sub-channels, each sub-channel can be treated as a flat fading, so the interference among the various signals is eliminated.

4 Fault location method of the power communication room based on active detection

The monitoring system of the power communication room ensures that the fault can be quickly resolved after the alarm is issued, but there are problems with the way of passively waiting for the alarm information [10]. Therefore, with the support of the Internet of Things technology, this paper proposes a fault location method of the power communication room based on active detection.

4.1 Fault location mechanism of the power communication room based on active detection

Aiming at the fault location of the power communication room, this paper divides it into three stages, namely fuzzy fault detection, detailed fault detection and fault judgment. Among them, the fuzzy fault detection stage determines the initial detection set, the detailed fault detection stage determines the detailed detection set on the basis of it to ensure the integrity of the detection data, finally the fault judgment stage uses the results of the detection set of the first two stages to determine the fault position.

As the beginning of the entire location method, the fuzzy fault detection involves the installation position of the detection signal transmitting device. This device can be installed in the location of the sensor of the Internet of Things, and the transmitting device is required to transmit detection signals to all nodes in the network. In the fuzzy fault detection stage, the detection set from each detection signal transmitter to all other network nodes is used to form the initial detection set T_0 . Secondly, the greedy algorithm is used to solve the minimum detection set that can cover the entire network to form the fuzzy detection set T_1 ; Finally, according to the initial detection set, the detection signal transmitter is operated and the return signal is fed back to the control center.

The fuzzy detection set cannot provide enough data for fault location, so the detailed fault detection stage is

needed to efficiently obtain more detailed detection results. In the detailed fault detection stage, the candidate detection set T_2 is first established, which is obtained by subtracting the fuzzy detection set T_1 from the initial detection set T_0 ; secondly, the detection value of each detection in the candidate detection set is calculated and sorted, and the largest detection t_1 is selected, and add the detection t_1 to the detailed probe set T_3 and delete it in the candidate detection set; then add the detection t_1 to the network to interact, and update the value of the detection in the candidate detection set, among them, the submodular of the detection value function can be used to reduce the scale of updating detection value. Then, sort the candidate detection set again, and select the largest detection t_2 , then repeat the above operation. Perform the above loop process until the detection cost reaches the maximum value or the candidate detection set is empty, and the final detailed detection set T_3 is obtained. Finally, according to the detailed detection set, the detection signal transmitter is operated and the return signal is fed back to the control center.

As the final loop, the fault judgment stage determines the faulty equipment and the faulty line set based on the detection results of the fuzzy detection set and the detailed detection set to ensure that the fault set should be able to explain all the fault information in the detection result. Among them, the detection results of the fuzzy detection set and the detailed detection set can be represented as the detection fault bipartite graph shown in Figure. 1, part of the figure is the set of fault sources, including faulty equipment and faulty lines, and the other part is the set of failure detection, and the connection line indicates that the detection in the fault state includes the equipment or line that connected to it in the figure. The specific content of the fault judgment stage is to explain the detected fault bipartite graph, and it needs to meet the requirement of explaining all detection in the fault state with the minimum faults. Therefore, this paper uses the minimum fault algorithm (MF) to determine the fault.

Figure1. Detection fault bipartite graph

4.2 Minimum detection set algorithm

The minimum detection set algorithm aims to select as few detections as possible from the initial detection set, so that the path through all equipment and lines. Because there is no isolated equipment in the network, all equipment is connected by lines, so it is only necessary to ensure that all lines are covered, and accordingly all

equipment will also be covered [11]. Based on the greedy algorithm, this paper takes the following steps to find the minimum detection set:

- 1) Firstly, set a set Y to store all the lines covered by the fuzzy detection set, which is initially empty.
- 2) Set a variable J for each detection, indicating the number of lines in the detection that are different from the lines in Y , and initially it is the number of all lines in the detection.
- 3) Select the detection with the largest value J , count it into the fuzzy detection set, and delete it from the initial detection set.
- 4) Update the value J of each detection in the initial detection set. If all lines in the network are not fully covered by the set Y , go to step 3, otherwise, stop the calculation and obtain the final fuzzy detection set.

4.3 Detection value and its submodular

At each step in the selection process of the detailed detection set, the detection that contributes the most to the fault location needs to be selected, so the detection value is taken to measure it. Specifically, the detection value can be divided into two aspects, one is the reduction degree of network uncertainty, and the other is the number of important nodes in the detection.

The uncertainty function of the network is not unique, but it has the same feature, that is, it is obtained based on the state of the network X , and it is set to $H(X)$. It is easy to know that the process of detection is the process of continuously reducing network uncertainty, and the detection set is set to T , so it is obviously $H(X|T)$ less than $H(X)$. In order to measure the degree of each detection on reducing network uncertainty, a gain value $G(t_i)$ is introduced, as shown in Equation 1.

$$G(t_i) = H(X|T_i) - H(X|T \cup t_i) \quad (1)$$

Therefore, combining the number of important nodes of each detection $N(t_i)$, the detection value of each detection $P(t_i)$ can be obtained, as shown in Equation 2.

$$P(t_i) = \alpha G(t_i) + \beta N(t_i) \quad (2)$$

Among them, α and β respectively indicate the importance of the two aspects in the detection value, which can be adjusted according to the needs of different networks.

In the detailed detection stage, each update of the detection value is not a small amount of calculation. However, the fault location has high requirements for timeliness. Therefore, the submodular of the detection value function can be used to obviously reduce the amount of calculation. Specifically, when the detection value function satisfies the submodular requirement, after a detection enters the network for interaction, the detection value of all other detections will decrease. Therefore, if the detection with the largest detection value after the update still has higher detection value than the detection value of other detections before the update, the detection is the selection of next loop, and

there is no need to update the detection value of other detections.

4.4 Minimum fault algorithm

The minimum fault algorithm is the core algorithm of fault judgement, and it aims to explain all the fault information obtained by fault detection with the minimum faults [12]. The specific steps are as follows:

1) Firstly, O is used to indicate the fault area, K is used to indicate the connection line between the fault area and the non-fault area, and V(i) and L(i) are used to indicate the candidate set of the faulty equipment and faulty line, respectively.

2) The detection set in the fault state is extracted from all the detection results to form the fault area O.

3) Check each line in the network. If one end belongs to O and the other end does not belong to O, the line is the connecting line between the fault area and non-fault area, and count the line to K.

4) Use a $|k|$ bit binary number to enumerate the states of each connected line at the same time. There are $2^{|k|}$ kinds of combinations of different states of the connected line, so that each combination is further analyzed when $i=0, 1, \dots, 2^{|k|}-1$.

5) For each combination i, there are $|k|$ connected lines, then further analysis is performed for each connected line: if the code of a connected line in combination i is 1, it means that there is fault on the connection line, then Count this connection line into L(i); if the code of the connection line in combination i is 0, it means that there is no fault on the connection line, but that there is a fault on the end of the connection line that locates in the fault area, then count the end into V(i) after confirming that the end is not in V(i).

6) After analyzing all combinations, find the combination whose $|V(i)|+|L(i)|$ is smallest, and treat this combination as the final fault set.

5 Conclusion

The paper adopts a combination of passive management and active management for fault management. Based on the Internet of Things technology, passive management is achieved by building a monitoring system of the power communication room, and active management is achieved by proposing a fault location method based on active detection. As a result, fault harmfulness is reduced. This paper has certain reference value for fault monitoring and fault location in the future.

References

1. TANG Naichuan. Intelligent Substation [J]. Equipment Machinery, 2010, 000 (003): 13-18.
2. LONG Jigang. Fault Treatment and Maintenance Analysis of Communication Power Supply in Electric Communication Network [J]. Digital Communication World, 2020 (06): 44-45.
3. ZHOU Jian, LI Yongjun. Composition and Function Design of Centralized Monitoring System in Power Communication Room [J]. Automation Application, 2019 (01): 70-71+77.
4. CHEN Sichao, LV Bin and WAN Yanzhen. Centralized Monitoring System and Its Application in Power Communication Room [J]. Smart City, 2016, 4 (17): 157-158.
5. QU Xianghua, LI Bo. Research and Design of Power and Environment Monitoring System in Power Communication Room [J]. Automation Technology and Application, 2019, 38 (10): 152-155.
6. YU Hao, ZHANG Lu and KUAI Wenke. Analysis of Networked Centralized Monitoring System and Technology for Power Communication Machine Room Equipment [J]. China New Communications, 2019, 21(12):38.
7. ZHAI Dani, HUANG Weidong. Application of Internet of Things in Disaster Relief Material Management [J]. Journal of Nanjing University of Posts and Telecommunications (social science edition), 2012, 14 (01): 56-60.
8. PAN Qingliang, YU Shijun, LIN Liumeng, et al. Application Research of Internet of Things Perception Technology in Emergency Response System [C]. Chinese Command and Control Institute. Proceedings of the 4th China Command and Control Congress. Chinese Command and Control Institute: Chinese Command and Control Institute, 2016: 63-67.
9. WANG Dezhen. Communication Design of Power System Based on Internet of Things Technology [J]. Electronic Production, 2020 (11): 92-93.
10. SHI Min. Fault Diagnosis and Treatment of Power Communication Network [J]. Guizhou Power Technology, 2013, 16 (02): 65-66.
11. ZHU Yanpei. Fault Location Mechanism of Integrated Data Network Based on Interactive Active Detection [D]. Beijing University of Posts and Telecommunications, 2018.
12. ZHAO Canming, LI Zhuhong, TAO Lei, et al. Fault Location of Power Communication Network Based on Fault Propagation Model and Supervised Learning [J]. Computer Applications, 2016, 36 (04): 905-908+922.