Construction of integrated sensing and control system for intelligent power distribution room based on multi-sensors

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ABSTRACT

In order to improve the environmental monitoring and operation management level of the power distribution room, this paper launches the construction of an integrated sensing and control system for intelligent power distribution room based on multi-sensors. In this paper, a scheme of integrated sensing and control system for intelligent power distribution room is proposed, and a multi-sensor structure is designed. Each sensor module converts the information related to gas, temperature and humidity into electrical signals or digital signals, and then the microprocessor processes and stores the data at the same time. When the detected parameters have exceeded the threshold set by the system, the upper computer displays the abnormal operation of the power distribution room. Aiming at three data fusion structures of multi-sensor parallel distributed detection fusion system, a soft threshold decision wavelet domain filtering algorithm is adopted, and this algorithm is effectively introduced into the multi-sensor parallel distributed detection data fusion structure. The results show that in the process of temperature and humidity measurement, the maximum relative error between the temperature measured value and the reference value is 2.6%, and the maximum relative error between the humidity measured value and the reference value is 0.3%, both of which are much larger than the relative error of the gas module measurement, but all meet the requirements. It is proved that the sensor meets the field application requirements of sensor equipment.

Keywords: Multi-sensor; Intelligent power distribution room; Integrated sensing and control.

1. INTRODUCTION

The stable and reliable operation of the distribution room not only directly affects the operation reliability of the distribution network, but also relates to the power consumption quality of users, which requires higher accuracy and speed of data transmission. In the event of an emergency, the backstage emergency commanders have insufficient control over the scene situation, which affects the time to rush to repair power [1-2].

As the front end of the monitoring system of the power distribution room, the sensing equipment in the power distribution room is in direct contact with the surrounding environments that need to be detected, and its performance and operation and maintenance efficiency directly affect the intelligent transformation level of the power distribution room. In these systems, the diversity of data representation, data capacity and data processing speed have greatly exceeded the comprehensive ability of human brain, and data fusion technology came into being [3-4]. With the increase of sensor subsystems, the failure rate also increases. When a subsystem fails to be detected and isolated in time, the failure data will pollute the whole system, which will reduce the reliability [5]. Literature [6] introduces an intelligent monitoring sensor network for substation equipment and an integrated intelligent monitoring device for substation equipment based on cloud platform, which realizes distributed calculation, fault diagnosis and early warning functions. Literature [7-8] puts forward the concept of intelligent power distribution room based on power distribution Internet of Things, and points out that intelligent power distribution should have three basic characteristics: hardware platform, software mobility and communication standardization. Based on the simulation and calculation of the temperature field in the power distribution room, an intelligent energy-saving ventilation system is developed, and did not involve the development or practical application of the monitoring system [9].

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Rainwater infiltration, dust accumulation and interference of wild animals lead to equipment tripping in the distribution room, which affects the normal power consumption of users [10]. The integrated sensing and control system of intelligent distribution room is a new intelligent node of distribution network, which is developed on the basis of tracking the development of international advanced technology and combining the characteristics of urban and rural distribution network systems. It is applied to the integrated sensing and control system of intelligent power distribution room, which further improves the integration level and information interconnection ability between devices and realizes remote intelligent monitoring of devices.

2. RESEARCH METHOD

2.1 Overall structural design of the system

The integrated sensing and control system of intelligent power distribution room is powerful, which can be applied to power distribution units of different grades and scales, and can determine the priority of data collection according to the importance of data information, and complete the collection work including non-electrical parameters, power grid parameters, power quality, metering parameters and operating conditions. Strict control is mainly carried out through operation record management, use right management and handover management.

According to the importance of data information, the priority of information collection is determined, including power grid parameter collection, non-electric parameter collection, metering parameter collection, power quality parameter collection and working condition information input and output. . Fault analysis: every time a fault occurs, the system records fault information such as fault time, fault substation, fault reason and fault variables, providing data for user fault analysis. Through related technical equipment, the master station layer can transmit and process all the data of the whole system. In addition, the main station layer is also analyzing video and image information, fault information and alarm information, and interacting with other systems. Through the selection of optical fiber private network, GPRS, 4G/5 G network and other technologies, the operation reliability and economy of intelligent distribution room are realized.

Common network architectures are divided into client/server mode and browser/server mode. The two modes are called C/S mode and B/S mode respectively. With the development of Internet, these two network architectures are widely used [11]. The advantages of C/S architecture are rich interface and operation options, high security and fast response. However, the C/S architecture has narrow application and high maintenance cost, so the software can only be used after installation. The monitoring system proposed in this paper runs in LAN and should adopt B/S architecture. Only by fully mastering the content, process and transmission mechanism of the protocol can we accurately grasp the communication data and diagnose the errors in the communication process in the development of the integrated sensing and control system of the intelligent distribution room.

In this scheme, the situation awareness is realized by monitoring and uploading the real-time data of switchgear status, power transmission status and comprehensive environment in the intelligent distribution room. The platform has the functions of information fusion and multi-dimensional situation awareness, which is helpful for staff to analyze data and find early faults of equipment and reduce the cost of manual inspection. The integrated sensing and control system of intelligent power distribution room is shown in Figure 1. Main control terminal, power distribution terminal unit, power distribution room display screen, background monitor, large screen of monitoring center and communication system.

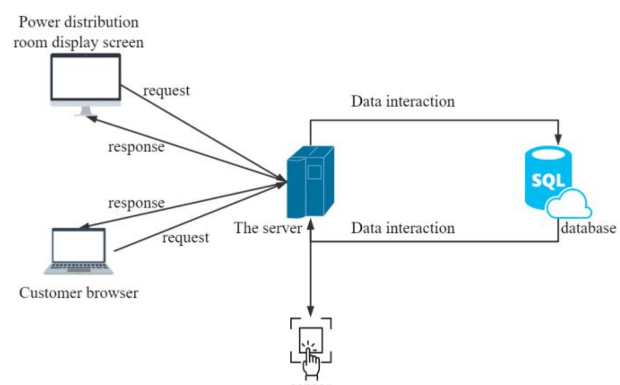

Figure 1. Integrated sensing and control system of intelligent power distribution room

If the construction is difficult and the distribution equipment is scattered in mountainous areas, the offline operation management network mode can be adopted to realize the viewing and analysis of the operation data of the distribution network. Ring network or dual-network redundancy structure is often adopted between station control layer and communication management layer, which can improve the stability of system operation. In the actual design process, according to the specific situation, offline access or wireless communication mode can be adopted between the two levels.

In the whole intelligent transformer room integrated sensing and control system solution, the intelligent gateway, various switching/analog devices and sensor devices needed in power management are covered. At the same time, one or more transformer room devices can be accurately managed and controlled through various terminal devices (computers, smart phones and tablets), so as to realize transparent monitoring and management of electrical fire hazards. Use automatic/manual methods to remotely detect the operation of the equipment in the power distribution room within the data authority. Detailed inspection list can be made, and regular and batch inspections can be carried out for different sensing equipment and execution equipment, and data analysis and early warning can be carried out for inspection reports.

2.2 Multi-sensor structure design

At present, the existing sensors in the distribution room are generally single-purpose design, each sensor measures and monitors a single gas, and the sensor is bulky and inconvenient to install. The bus connection of high-voltage cabinet, the disconnector or contact, the low-voltage outlet of transformer and other equipment connections are all sensitive parts of heating. Too high or too low temperature will reduce the insulation of equipment connections, which will lead to equipment damage. Multi-sensors can monitor and analyze the concentration, temperature and humidity of sulfur hexafluoride, oxygen and ozone gas in various environments such as intelligent electrical room and gas insulated switch in high-voltage switch room, instead of using multiple single-parameter sensors to monitor the target environmental state. It can judge whether the range of each detection parameter exceeds the threshold, and make fault early warning for the operation state of the distribution room according to the intelligent prediction model of abnormal state.

Control methods are generally divided into local control and remote control. Local control mainly controls the functions of the system background [12], and remote control mainly controls the monitoring system in the power distribution room. Before completing the control of the system, the first task is to complete the centralized access to the sensors of the system and read the interface parameters of each sensor in detail. If an alarm signal is generated, it can be popped up quickly in the form of pop-up to remind the operator to stop the current operation, and the alarm signal should be checked and processed quickly immediately; SMS reminder mode, when the alarm signal with significant characteristics is generated, data can also be reminded by SMS, so that the operator is not at the system site, which affects the rapid response of the system alarm.

Due to the leakage of sulfur hexafluoride switchgear in the distribution room, it is necessary to monitor sulfur hexafluoride and oxygen gas. In the process of partial discharge, the partial discharge of switchgear can be indirectly detected by monitoring the change of ozone concentration. The multi-sensor structure designed in this paper is shown in Figure 2. When working, each sensor module converts the information related to gas, temperature and humidity into electrical signals or digital signals, and then the microprocessor processes and stores the data at the same time, and transmits the data information with the upper computer through the wireless transmission module or wired network. When the detected parameters have exceeded the threshold set by the system, the upper computer shows that the distribution room is running abnormally.

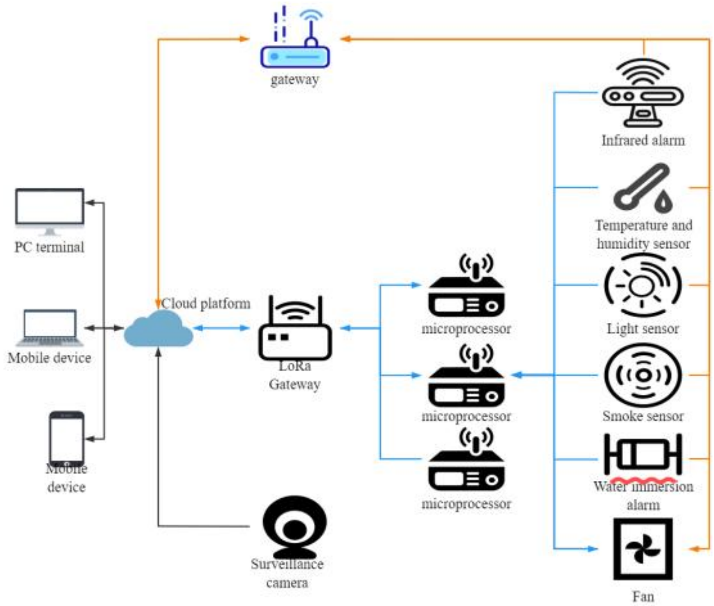

Figure 2. Multi-sensor structure

Among the three fault types tested in this system, some of the eigenvalues extracted by these two sensors are very close, so there may be misjudgment. For each sensor, the possibility of which type of fault is detected is expressed by the membership value, so that two groups of six membership values can be obtained.Aiming at three data fusion structures of multi-sensor parallel distributed detection fusion system, this paper puts forward a theoretical analysis method of the relationship between fusion rules and local decision rules under Neyman-Pearson criterion, and gives the theoretical derivation of two sub-optimal systems and global optimal systems. Soft threshold decision wavelet domain filtering algorithm is adopted, and this algorithm is effectively introduced into multi-sensor parallel distributed detection data fusion structure.

In this paper, Donoho's wavelet domain filtering algorithm based on soft threshold decision is adopted, and it is used to suppress the noise of non-stationary radar echo signal, which plays a good role, even in low SNR. Below we give the observation of radar echo signal:

$$x_i = f_i + \delta z_i \tag{1}$$

Where: f_i stands for signal, z_i stands for white noise with $N(0,1)$ distribution, and δ stands for noise level.

We use soft clipping function to threshold the coefficients in wavelet domain. The soft clipping function is:

$$\eta_T(x_{j,k}) = \begin{cases} 0, & |x_{j,k}| \le T \\ \operatorname{sgn}(x_{j,k})(|x_{j,k}| - T), & |x_{j,k}| > T \end{cases} \tag{2}$$

Where $\eta_T(x_{j,k})$ represents the wavelet coefficient after threshold processing, and T represents the threshold of soft clipping function.

The measurement function assignment value $m_i(q_j)$ of the uncertainty q of sensor i is:

$$m_i(\theta) = \frac{N_s(1-R_i)(1-\alpha_i\beta_i\omega_i)}{\sum_{j=1}^{n} C_i(q) + N_s(1-R_i)(1-\alpha_i\beta_i\omega_i)} \tag{3}$$

Where $C_i(q)$ is the correlation coefficient of sensor i to target type q; N_s is the total number of sensors; ω_i is the environmental weighting coefficient of sensor i, and its value is [0, 1]; α_i is the maximum correlation coefficient of sensor i; β_i is the relevant assigned value of sensor i; R_i is the reliability coefficient of sensor i.

The total mean square error is:

$$\sigma^2 = \sum_{i=1}^{n} W_i^2 \sigma_i^2 \tag{4}$$

Where σ_i is the variance of the i sensor.

3. EXPERIMENTAL ANALYSIS

The integrated sensing and control system of intelligent power distribution room developed in this paper has been applied and tested in a power distribution room of a residential district.

After the system is started, it immediately enters the monitoring main interface, which mainly gives the operating environment data of the power distribution room. The monitoring system can also give the real-time changes of the environment data, and the time interval is 30 minutes, as shown in Figure 3, which shows the dynamic curve of the environment gas data.

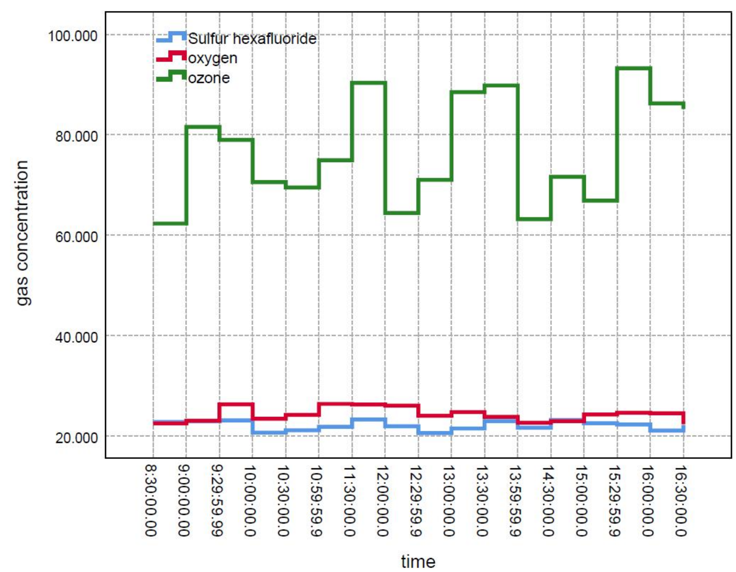

Figure 3. Dynamic curve of ambient gas data

As can be seen from the above figure, the concentration of sulfur hexafluoride in the distribution room remains stable in a short time, and the concentration of oxygen and ozone changes greatly in a short time. Therefore, it is necessary to better control the work of auxiliary equipment and control the humidity and gas concentration within a reasonable range.

The relative error of multi-sensor experimental data is shown in Table 1, the relative error is 0%, and the maximum relative error between oxygen measured value and reference value is 0.3%. In the process of temperature and humidity measurement, the maximum relative error between the temperature measured value and the reference value is 2.6%, and the maximum relative error between the humidity measured value and the reference value is 0.3%, which are far greater than the relative error of the gas module measurement, but all meet the requirements. It is proved that the sensor can realize the simultaneous on-line detection of sulfur hexafluoride, oxygen and ozone gas volume fraction and temperature and humidity in the intelligent distribution room, which meets the field application requirements of sensor equipment.

Table 1. Relative error of multi-sensor experimental data

Number of experiments	Volume fraction			temperature	humidity
	sulfur hexafluoride	oxygen	ozone		
1	0	0.3	0	2.2	1
2	0	0.3	0	0.6	0.9
3	0	0	0	0.3	3.8
4	0	0	0	1	2.5
5	0	0.3	0	2.6	1.9

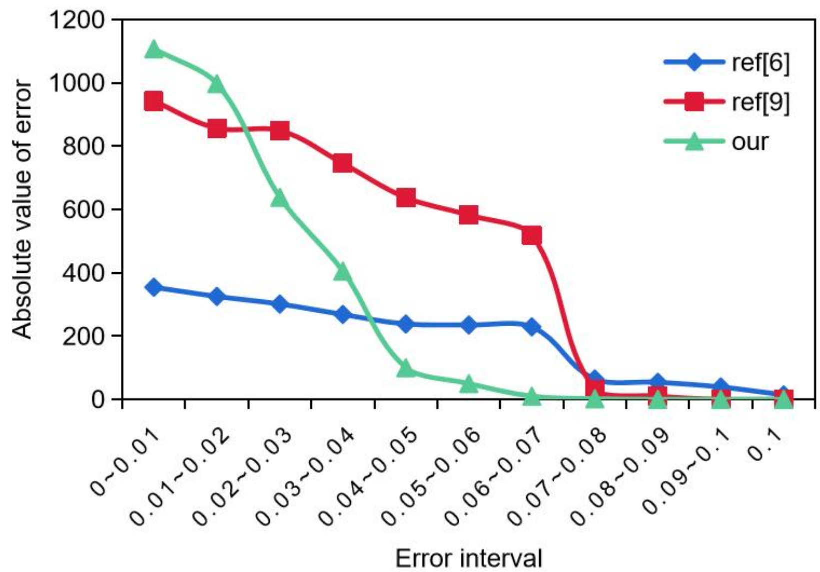

Figure 4. Distribution of absolute value of error in each error interval

Based on the results of the above analysis, the data provided by 500 sensors in a data acquisition system are fused and analyzed. Figure 4 shows the distribution of the absolute value of the error in each error interval. It can be seen that the fusion effect of this algorithm based on the measured variance is the best, so it can be seen that this algorithm can effectively improve the accuracy of data fusion and play an important role in reducing the error of data fusion in multi-sensor data acquisition system.

4. CONCLUSION

As the front end of the monitoring system of the power distribution room, the sensing equipment in the power distribution room is in direct contact with the surrounding environments that need to be detected, and its performance and operation and maintenance efficiency directly affect the intelligent transformation level of the power distribution room. In this paper, a multi-function sensor is designed, which can monitor the concentration, temperature and humidity of various gases in real time. It is applied to the integrated sensing and control system of intelligent power distribution room, which further improves the integration level and information interconnection ability between devices and realizes remote intelligent monitoring of devices. The results show that in the process of temperature and humidity measurement, the maximum relative error between the temperature measured value and the reference value is 2.6%, and the maximum relative error between the humidity measured value and the reference value is 0.3%, both of which are much larger than the relative error of the gas module measurement, but all meet the requirements. It is proved that the sensor can realize the simultaneous on-line detection of sulfur hexafluoride, oxygen and ozone gas volume fraction and temperature and humidity in the intelligent distribution room, which meets the field application requirements of sensor equipment.

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