Research on residual current warning technology based on big data analysis

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Abstract—Residual current is the main cause of electrical fire. The traditional residual current monitoring methods often give delayed alarm, false alarm or even missed alarm, which cannot be applied in practice. This paper put forward the residual current detection solution based on big data analysis. The big data analysis based on residual current, temperature and humidity could detect residual current anomaly information as early as possible, realize fault monitoring and early warning. This method was applied to important facilities such as substation, data center. It could reduce or eliminate fire hazards, and provide decision basis for electrical fire warning.

1. Introduction

With the development of economy, electrical fire accidents are increasing year by year in China. From 2012 to 2016, there were 1,595,000 fires in China, among which electrical fires accounted for 29.5% of the total and reached 471,000, causing 14,440 casualties and direct economic losses of 19.8 billion YUAN [1]. From January to October in 2020, a total of 196,000 fire accidents occurred, among which electrical fires accounted for 32.1% of the total, far exceeding fires caused by other factors [2]. According to the causes of electrical fire, electrical fire accidents are mostly caused by leakage current generated by grounding fault short circuit [3-5].

When the insulation of the power lines decreases, leakage currents can be monitored and cause grounding fault. It is an important factor for electrical fire. When the leakage current is small, there may not be an immediate fire. However, with the increase of leakage current, the temperature of fault point will rise rapidly, and eventually lead to the occurrence of fire [6]. Therefore, residual current fire monitoring system is a very critical equipment, which has been widely used in electrical fire monitoring [7-11].

However, there are shortcomings for the traditional residual current monitoring systems, that processing method is relatively simple and that the intelligence degree is low. These monitoring systems often give delayed alarm, false alarm and even missed alarm, that causes great economic losses to the people. The prevention and control of electrical fire safety should focus on pre-prevention and follow the principle of the early detection, prevention and control.

This paper proposed the residual current monitoring and early warning scheme based on big data analysis, which is applicable residual current monitoring of important facilities such as substations and data centers. The residual current, temperature and humidity are collected in real-time using newly designed and developed senor terminal and management terminal. The new algorithm based on the processing and analysis of big data could find out the abnormal residual current as early as possible,
accurately predict the risk, reduce or eliminate fire hazard, and provide decision basis for the electrical fire warning.

2. System architecture
The residual current monitoring and early warning system is mainly composed of three devices, namely sensing terminal, management terminal and monitoring terminal. The overall architecture of the system is shown in Fig. 1.

2.1. Sensing terminal
The sensing terminal collects the residual current, ambient temperature and humidity of each feeder branch of the AC power system. Ambient temperature and humidity are one of the important parameters for residual current analysis. The integration of ambient temperature, humidity and residual current monitoring can provide effective data support for the early warning analysis of residual current. The key technical indicators are shown in the Table 1.

| Item                  | Residual current | Ambient temperature | Relative humidity |
|-----------------------|------------------|---------------------|------------------|
| Measurement range     | 10mA~10000mA     | -20℃ ~ +85℃        | 0-100%           |
| Measurement accuracy  | 0.5 level        | ±1℃                 | ±1%              |

2.2. Management terminal
The management terminal can collect the residual current and other data from the sensing terminal, and to store and record steady-state recording and transient recording of fault alarm using wireless communication.

The fault wave-recording is for management terminal to record steady-recording of residual current and dynamic recording of the fault data in a specific time when the fault occurs. The function is used mainly to achieve data traceability and data backup, and to provide accurate and reliable data support for fault analysis. The leakage current, temperature and humidity. The leakage current, temperature and humidity are recorded for wave-recording.

The key technical indicators are as follows:
(1) Steady-state recording. The recording period is 1s, and the recording time is 6 months;
(2) Transient recording. The sampling frequency of recording is 4K Hz. It can record the transient waveform from 1s before leakage to 10s after leakage. A maximum of 500 transient recording waves can be recorded.
2.3. Monitoring terminal

The monitoring terminal is the core of data collection, calculation, and management for residual current monitoring system. There are the functions including data collection and data analysis.

2.3.1. Data collection

Real-time data collection. The monitoring terminal can collect the leakage current, temperature and humidity and device status. The monitoring component can collect and display all the data and status information.

History data collection. It includes historical alarm data and wave recording data. The history data is stored in the form of files in SD cards through the file system. User can view a maximum of 1000 pieces of historical data through the device interaction and copy data through to USB storage.

2.3.2. Data analysis

Fault location. The monitoring terminal saves the sensor ID configured on the connected sensing terminal and identifies the specific branch ID. When the leakage current alarm exceeds the alarm threshold, the monitoring terminal determines the branch alarm to locate the specific branch.

Fault warning. The thresholds are set for the monitoring terminal according to the real-time and history monitoring data values. Based the early-warning algorithm of big data analysis, it can analyse the trend change of leakage current, temperature, and humidity. When fault risks are found, the early warning is sent for user.

3. Methods and data analysis

3.1. Comprehensive analysis algorithm

Early warning analysis of residual current, is a comprehensive consideration to the occurrence of residual current principle, reason, and environmental factors such as temperature, humidity condition. Based on the residual current, temperature, humidity data in a period, the algorithm can analyse the tendency of residual current. When lope-change trend or absolute value of residual current exceed the threshold, the algorithm will give a early warning.

The principle of the algorithm is shown as follow. When residual current reaches a certain value, the ambient temperature will accumulate and increase faster than residual current value. In addition, in some cases, due to the poor insulation of the cable, the leakage may be large or small, and the occurrence time is short. Therefore, the fault cannot easily be detected just using the temperature value. However, the accumulated temperature can be determined to a certain extent, and then the comprehensive analysis of environmental humidity value can be forecasted.

The main flow of the algorithm is shown in Fig. 2.

1. Data collection and monitoring. Collect and monitor the ambient temperature, humidity and residual current value regularly.

2. Calculation of difference.

When temperature value is collected, the difference between the current temperature value and the last temperature value is calculated and stored as a signed number.

$$\Delta T = T_n - T_p$$  \hspace{1cm} (1)

Where, $\Delta T$ is the temperature difference, $T_n$ is the current temperature value, $T_p$ is the last temperature value.

3. Difference analysis

When the temperature exceeds the threshold, the change of slope rate for the storage temperature differences is calculated and analysed. If the slope rises gradually, it indicates that the temperature has begun to rise and is close to the threshold value. When that happens, residual current values begin to monitored.

4. Residual current monitoring
When the current residual current exceeds the threshold, start fast sampling, that is increasing the frequency of residual current sampling originally and starting humidity data analysis.

(5) Humidity data analysis
The purpose of humidity data analysis is to detect transient faults. The principle is that the increase of humidity will have a greater impact on leakage. If the cable insulation skin is broken, the increase of humidity will lead to an increase of residual current. That may lead to a large leakage current in an instant state. The slope algorithm can be used to analyze the trend of humidity change over a period.

If the humidity increases constantly and reaches the maximum value in a certain period, a preliminary warning can be given at this time to warn the environment of possible leakage caused by insulation damage, and double sampling can be carried out at the same time. If the residual current value exceeds the threshold, upgrade the alarm or direct alarm. If it is not, the conventional algorithm is used to analyze the trend of residual current and carry out early warning.

![Flow chart of residual current comprehensive analysis algorithm](image)

**Fig. 2 Flow chart of residual current comprehensive analysis algorithm**

3.2. Residual current conventional algorithm
Conventional early warning algorithm is based on the variation rule of residual current value of different fire accidents: when the residual current value has been abnormal, it will show a certain trend characteristic, so we can use the variation trend of residual current value to realize the monitoring and early warning of electrical fire accidents.

Viewing the change of accident fire, there are generally three categories: one is ongoing fault, one is gradual fault, the other is mutant fault. If the gradual fault is not handled in time, it will gradually
develop into a mutant fault, and the change situation is irreversible. Therefore, conventional data analysis will focus on three scenarios:

1. **Ongoing type**
   If the residual current value suddenly reaches the threshold of warning, it indicates that the fault is occurring and an alarm will be generated immediately. The thresholds for warning can be set based on application scenarios.

2. **Gradual type**
   Warning conditions are that the slope of residual current value increases constantly to a certain threshold or that the residual current values increase to the threshold of warning.
   The sample dataset A of monitoring is shown in Figure 3. Within 24 hours, the residual current values continued to increase slowly. When the value exceeded to the threshold at point a which was set to 3.5A, the warning was given out.

3. **Mutant type**
   When the leakage fault happens, residual current value continues to increase. The residual current values not exceed the threshold; however, the slopes of residual current exceed the threshold. Then the warning will be given out.
   The sample dataset B of monitoring is shown in Fig.3. The residual current values continued to increase, but no exceeded the threshold of warning that was set to 3.5A. However, the slope of residual current values also increased and exceeded the threshold at point b and c which set as 0.5. Then the warning was given out.

![Fig. 3 The Sample data of residual current conventional analysis algorithm](image)

### 4. Conclusion

The research work has successfully proposed the residual current monitoring and early warning scheme based on the big data analysis. The residual current, temperature and humidity were collected in real-time using newly designed and developed sensor terminal and management terminal. The new algorithm based on the processing and analysis of big data could find out the abnormal change of residual current as early as possible and realize the fault monitoring and early warning. It is useful for important facilities such as substations and data centers to reduce or eliminate the fire hazard, and provide decision basis for the electrical fire warning. In the future, it is considered that neural network
algorithm will be used for residual current monitoring and early warning to avoid threshold configuration.

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