Design and Application of Portable Fault Indicator Detector Based on Internet of Things

Long Qiu Feng¹, Wen Yi¹, Xiao Xiaobing¹, Feng Ling Cheng², Xu Shihua³ and Zhang Wei³

¹ Electric Power Research Institute of Guizhou power grid Corp, 550001 Guiyang, Guizhou, P. R. China
² Fujian Automation Electric Power Technology Co., Ltd., 350001 Fuzhou, Fujian, P. R. China
³ Jicheng Electronics Co., Ltd, 250100, Jinan, Shandong, P. R. China

E-mail: zhangweiieslab@163.com

Abstract. In order to solve the problem of detecting the fault indicator in the field, a design scheme of the portable fault indicator detector based on the Internet of Things is proposed. Firstly, the overall architecture of portable fault indicator detector based on Internet of Things is designed. Secondly, the system architecture of portable fault indicator detector is designed from two parts and seven aspects. Then, the hardware architecture of UPS power module, AC power amplifier module and human-computer interaction module is designed in detail. Finally, the main functions and detection methods of the portable fault indicator are discussed. The case analysis shows that the portable fault indicator detector based on the Internet of Things has greatly improved the time, manpower and cost of detection compared with traditional detection methods, and can conveniently meet the needs of on-site inspection personnel.

1. Introduction

In order to accelerate the construction and transformation of distribution network, the State Energy Administration of China issued the Action Plan for the Construction and Transformation of Distribution Network (2015-2020). China plans to comprehensively improve distribution automation coverage during the 13th Five-Year Plan period, with an overall coverage rate of 90% in 2020. Therefore, in recent years, a large number of distribution automation terminal equipment is connected to the network, which effectively improves the reliability of the distribution network [1-3].

As an important terminal equipment for feeder automation, the fault indicator is widely used in the current distribution network because of its small size, low price, live installation, and good adaptability to short circuit and ground fault [4-5]. However, in practical applications, due to the lack of effective detection means, the quality of the products is uneven, and many installed fault indicators have not been tested. In addition, the on-site environment is variable, such as large changes in temperature and humidity, dust, and untimely maintenance, which will result in damage to the accuracy of the acquisition device, resulting in a false alarm signal for the fault indicator during normal operation of the grid. The introduction of a large number of error signals leads to frequent misjudgements in traditional fault diagnosis based on fault indicators, losing its original significance [6-7].
The detection method for the fault indicator terminal is currently divided into two types, the first one is the laboratory detection method, and the second is the on-site detection method. The former needs to transport the fault indicators to the designated detection institutions and use special testing instruments for detection. This kind of detection method is mainly used in the case of large-volume offline detection, such as factory inspection and arrival inspection. The latter needs to use special detection instruments for on-site detection of the fault indicators to be detected, and does not need to transfer terminal equipment, which is convenient and fast, but the detection project is relatively simple compared with the laboratory detection method. This method is suitable for regular inspections and random inspections of fault indicators that have been run online. At present, there are more studies on the first laboratory detection method, but less on the second field detection method. Therefore, it is of great practical significance to study the on-site detection method of fault indicator and provide a convenient and simple portable detection method for ensuring the on-line operation quality of fault indicator and improving the reliability of power supply.

Firstly, the system architecture of portable fault indicator detector based on Internet of Things is designed. Secondly, the hardware architecture of portable fault indicator detector is designed. Then, the main functions of portable fault indicator are described. Finally, the detection methods of some functions are discussed.

2. Fault indicator detection system architecture based on internet of things

Internet of Things technology refers to an information transmission and exchange technology that intelligently identifies, traces and manages information through video recognition, sensors and other information sensing devices, and links any item to the Internet through a certain communication protocol for information transmission and exchange. Depending on the Internet of Things technology, the fast interconnection and interoperability of fault indicators, the portable detectors and the equipment production management system can be realized, and the on-line fast maintenance of fault indicators terminal can be realized.

Figure 1 shows the system architecture of the fault indicator detector based on the Internet of Things. Firstly, the portable fault indicator detector downloads the relevant information of the fault indicator from the production management system by scanning the two-dimensional code of the fault indicator to be detected, including manufacturer information, commissioning time, maintenance time and other related parameters. Secondly, the fault indicator to be detected is grouped according to the online operation, and one set of three probes is respectively placed in the area to be inspected of the portable fault indicator detector. Then, according to the detection procedure, corresponding operations are performed on the human-machine interface, and the function of detecting the fault indicator is detected. Finally, the test results are displayed in the human-machine interface, and the result information is uploaded to the production management system through the Internet of Things communication network.

In order to ensure information security, the portable fault indicator detector and the production management system exchange information through the secure access zone. The communication method can use optical fiber, carrier wave, wireless public network, wireless private network, NB-IoT and other communication means. In areas with weak signal intensity, concentrator can be used to collect and amplify signals by WiFi, Zigbee, Bluetooth, infrared and other means, and then to interact with data by means of Internet of Things communication.
3. Portable fault indicator detector system design

In order to realize the fast and convenient detection and maintenance of the on-site operation fault indicator, the portable fault indicator detector is designed according to the principles of economy, reliability, openness, scalability and maintainability. It achieves high cost performance, strong reliability, convenient expansion and simple maintenance.

3.1. Fault indicator detector system design

The portable fault indicator detector consists of 2 major 7 modules, two of which include the main unit and the power supply. The 7 major modules include UPS power module, analog circuit power supply module, high power switching power supply module, human-computer interaction module, source control system module, AC power amplification module, and up-converter coil module. Specifically as shown in Figure 2.

![Figure 2. Fault indicator detector system design](image-url)

**Figure 2.** Fault indicator detector system design

The portable fault indicator detector can generate a maximum 600A single-phase steady-state current, support the output of 15 mode state sequences, and support the detection of a group of three fault indicators at the same time. The power supply uses 750W high-power battery. The DSP uses a 600 MHz high performance Blackfin 532 processor. The processor has two 16-bit MACs, four 8-bit video ALUs, and a 40-bit shifter RISC-type register and instruction model. The core voltage is VDD 0.8V-1.2V. The regulator supports 3.3V-2.5V input voltage, supports PWM, and supports IrDA UART event processing. Its programming is simple, the compilation environment is friendly, and advanced debugging, tracking and performance monitoring functions are available.

**Figure 3.** UPS power module design

The system architecture of the fault indicator detector based on the Internet of Things

![Figure 1](image-url)

**Figure 1.** The system architecture of the fault indicator detector based on the Internet of Things
3.2. Fault indicator detector hardware design

3.2.1. UPS power module design. In order to facilitate the carrying of the fault indicator detector and to meet the field operation in the non-electrical area, the power module is designed as an embedded battery structure with a maximum output power of 750W. It consists of seven steps. Firstly, the AC 220V voltage signal is converted into DC signal through rectifier bridge, and then the waveform is corrected by inductance circuit, power factor correction circuit and control chip. Then the high-voltage direct current is transformed into 12 V low-voltage direct current by transformer, and the battery is charged. The battery is discharged by the inverter, and the DC current is converted to 220 V AC for output. As shown in Figure 3.

3.2.2. AC power amplifier module design. Based on cost performance, discrete components are selected for power amplifier circuit. Two-stage power amplification is adopted, that is, D-type power amplification and push-pull power amplification. The D-type power amplifier circuit adopts the IRS2092 chip of IR Company, and the output of the digital-to-analog converter (DAC) is preamplified, then the power amplifier circuit of the latter stage is driven, and the fault detection circuit is used. The input and output of the power amplifier circuit are protected to avoid being burned when a fault occurs. The power amplifier circuit of the latter stage is a push-pull power amplifier circuit of Class A and B, and the corresponding Metal-Oxide-Semiconductor (MOS) tube is at a static working point to improve the load capacity of the power amplifier circuit and reduce nonlinear distortion, output current is 15A AC sinusoidal waveform.

In order to reduce the interference between the instrument system board and the power amplifier board, a second-order low-pass filter is added between the signal source and the power amplifier circuit. Low noise operational amplifier OP07 and high stability polypropylene capacitor are used in the components, and their low pass frequency is 10 kHz. The specific design is shown in Figure 4.

3.2.3. Human-computer interaction module design. The human-computer interaction module consists of four parts: the liquid crystal part, the keyboard part, the communication part and the clock part. The liquid crystal part mainly realizes the display of the detection parameters, the output of the detection result, the display of the device information, etc.; the keyboard part mainly realizes the input of the detection parameter, the operation of the detection command, etc.; the clock part mainly realizes the time timing and control of the system; the communication part mainly realize the communication between the core control unit and the liquid crystal part, the keyboard part, the clock part. XC7Z020 of Xilinx Company is used as the core control board development tool, and MT41K256M16HA is used as the memory storage DDR. As shown in Figure 5.

4. Main function design of fault indicator detector

The main detection functions of the fault indicator detector include 10 kinds, which are short-circuit fault alarm detection, reclosing transient fault detection, reclosing permanent fault detection, load fluctuation anti-false alarm detection, transformer no-load switching inrush current anti-false alarm detection, line switching inrush current anti-false alarm detection, heavy load switching anti-false detection parameter, the operation of the detection command, etc.; the clock part mainly realizes the display of the device information, etc.; the keyboard part mainly realizes the input of the detection parameter, the operation of the detection command, etc.; the clock part mainly realizes the time timing and control of the system; the communication part mainly realize the communication between the core control unit and the liquid crystal part, the keyboard part, the clock part. XC7Z020 of Xilinx Company is used as the core control board development tool, and MT41K256M16HA is used as the memory storage DDR. As shown in Figure 5.
alarm detection, non-fault coincidence anti-false alarm detection, thrust current anti-false alarm detection, telemetry accuracy detection, live loading and unloading detection.

4.1. Short-circuit fault alarm detection
Short-circuit fault is one of the most common faults in feeder. Correct determination of fault area is the main purpose of installation of fault indicator. When the short-circuit fault occurs, the feeder flows through the short-circuit current, and the fault indicator will alarm and turn the card. Therefore, it is of great significance to detect the short-circuit fault alarm sensitivity of the fault indicator.

The portable fault indicator detector can output 30A steady-state current for 60s to simulate normal feeder load current; it can output 400A~600A high current for 100ms to simulate fault feeder short-circuit current. Specifically as shown in Figure 6.

Wherein, $\Delta I$ is the fault abrupt current, $T_1$ is the charging time, $T_2$ is the fault current duration, and $T_3$ is the duration after the trip.

The specific detection methods are as follows: 1) Turn on the power supply of the fault indicator detector. 2) Install the fault indicator probe on the portable detector. 3) Click on the short-circuit fault button and enter the short-circuit fault detection sequence. 4) When the fault detection sequence is completed, check whether the fault indicator has a sign of reversal, and check whether the fault indicator has a short-circuit fault alarm through wireless module or concentrator. 5) If the fault indicator is correctly flopped and the alarm message indicates a short circuit fault, the fault indicator is normal. 6) If the fault indicator is not correctly flopped or the alarm information is not displayed correctly, it can be judged that the fault indicator short-circuit fault alarm detection is not normal.

![Figure 6. Short-circuit alarm detection](image)

4.2. Reclosing transient fault detection
Transient fault is one of the most common faults of the feeder. When the fault occurs, the substation outlet breaker is often equipped with a reclosing function. The automatic closing of the breaker can avoid the power failure caused by the transient fault. However, when reclosing, due to the large inrush current instantaneously, the fault indicator often reports a fault current, so the reclosing fault detection is of great significance.

The portable fault indicator detector can output 30A steady-state current for 60s to simulate normal feeder load current; it can output 400A~600A high current for 100ms to simulate the fault feeder instantaneous fault current; it can output 0A current for continuous 0.2s to simulate transient fault circuit breaker trip; it can output 400A~600A high current for 100ms to simulate short-time inrush current caused by reclosing; it can output 30A steady-state current for 30s to simulate coincidence normal feeder load current after reclosing. Specifically as shown in Figure 7.

Wherein, $\Delta I$ is the fault abrupt current, $T_1$ is the charging time, $T_2$ is the fault current duration, $T_3$ is the power outage time, $T_4$ is the reclosing inrush current duration, and $T_5$ is the duration after the normal current is restored. Other methods of function detection are similar, and will not be repeated.

![Figure 7. Reclosing transient fault detection](image)

5. Case analysis
After using portable fault indicator detector in a certain place, 100 sets of fault indicators are detected on the spot. The minimum detection time (MT, unit is hour), the minimum number of detectors (MP),
the minimum detection cost (MS, unit is RMB Yuan), the total detection time (AT, unit is hour), the total number of detectors (AP), and the total detection cost (AS, unit is RMB Yuan) are shown in Table 1. Wherein, the detection costs are mainly labor costs and vehicle transportation costs.

Table 1. Intelligent distribution station operation statistics

| Method            | MT | MP | MS  | AT  | AP  | AS   |
|-------------------|----|----|-----|-----|-----|------|
| Traditional method| 2  | 3  | 500 | 400 | 350 | 60000|
| Portable method   | 0.3| 2  | 100 | 50  | 270 | 30000|

As can be seen from Table 1, the minimum detection time of the traditional detection method is 6.67 times that of the portable detection method; the total detection time of the traditional detection method is 8 times that of the portable detection method; the minimum number of detectors of the traditional detection method is 1.5 times that of the portable method; the total number of detectors of the traditional detection method is 1.29 times that of the portable method; the minimum detection cost of the traditional detection method is 5 times that of the portable method, and the total detection cost of the traditional detection method is 2 times that of the portable detection method. Therefore, compared with the traditional detection methods, the portable fault indicator detector has a great improvement in the time, manpower and cost of detection.

6. Conclusion
Firstly, the overall architecture of portable fault indicator detector based on Internet of Things is designed. Secondly, the system architecture of portable fault indicator detector is designed from two parts and seven aspects. Then, the hardware architecture of UPS power module, AC power amplifier module and human-computer interaction module is designed in detail. Finally, the main functions and detection methods of the portable fault indicator are discussed. The case analysis shows that the portable fault indicator detector based on the Internet of Things has greatly improved the time, manpower and cost of detection compared with traditional detection methods, and can conveniently meet the needs of on-site inspection personnel.

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