ISSN: 2414-1895 DOI: 10.6919/ICJE.202112_7(12).0069

Development of portable cable fault detection device

Lihua Huo, Yang Li, Jie Lu

State Grid Zhejiang Cixi City Power Supply Company, Zhejiang, China

Abstract

Efficient detection and accurate positioning of cable faults is the necessary backup guarantee for the safe and stable operation of the application system. However, the current cable fault detection and positioning technology has the problems of poor portability, low accuracy and high price, and the high-performance cable fault detection equipment and foundation still need to be developed. In order to solve various problems of cable fault detection in large equipment system, this paper designed a portable multifunctional cable fault detection device, proposed an improved secondary pulse method to locate the cable main insulation fault, and developed a DSP driver to access and control the tester. The experimental results show that the device has high accuracy, strong reliability, wide application range and good application prospect and market value.

Keywords

Cable; Fault detection; Secondary pulse; Positioning.

1. Introduction

The transmission of various accusations between modern large-scale application systems mainly depends on the laying of cables. However, there are many kinds of cables, and it is difficult to accurately detect and locate faults when faults occur. Therefore, it is increasingly urgent to design and develop cable fault repair technology for large-scale application systems [1]. The application of cable detection information technology has freed people from complicated troubleshooting work, improved the speed and performance of fault detection, and doubled the work efficiency, which has become the main development trend of cable detection work at present.

Under normal circumstances, the laying of power and communication cables is relatively hidden. Typical cables include buried cables, overhead cables, and internal cables with protective shells, which make it difficult to find and locate cable faults [2]. In addition, the traditional cable fault detection instruments connect the faulty cable to the instrument for detection after the cable fault, which is not real-time. At present, cable fault location methods mainly include bridge method, step voltage method, pulse current method, secondary pulse method, low voltage pulse reflection method, etc. [3-4]. In this study, an improved secondary pulse method is proposed to locate the cable main insulation fault, and the proposed method is verified by a case. The results show that the improved secondary pulse method can effectively locate the cable main insulation fault.

2. Principle and key technology of secondary pulse ranging

Under the action of high enough impulse voltage, the high resistance fault will generate short-circuit emission when it clicks through the arc, and a waveform with the same characteristics as the short-circuit test will be obtained, that is, the polarity of the test pulse is opposite to that of the echo pulse at the fault point. When the voltage reaches a certain value, when the voltage is very high and the field strength is large enough, a small amount of free electrons in the medium will collide and dissociate under the action of the electric field, and the free electrons will collide with neutral molecules to excite and dissociate them and generate new electrons and positive ions. That is, the fault point of the cable will be suddenly broken down, the voltage of the fault point will drop sharply to almost zero, and the current will suddenly increase, resulting in a discharge arc [5]. According to arc theory, the apparent resistance of this arc is very small, which can be considered as a low resistance or short circuit fault.

The key technology of the secondary pulse method is to avoid multiple step voltage reflection waves and inherent large cosine oscillation waveform generated by the fault point when the fault point is broken down by high voltage, and then the instrument sends another pulse within the duration of high voltage breakdown of the fault point, and records the reflected pulse of the fault point.

By simultaneously displaying the wave forms measured twice on the screen and aligning them with the starting point, it can be clearly found that the wave forms before the fault point overlap perfectly. Once passing the fault point, the waveform curve diverges obviously. Moreover, the inflection point of the fault point is very obvious, which is a standard waveform of short-circuit fault echo, which can well interpret the fault distance. Almost all high impedance faults are of this waveform with single characteristics.

3. Fault location based on improved secondary pulse method

3.1 Positioning method

Secondary pulse method, also known as high voltage arc reflection method, locates the fault point by transmitting secondary pulses. It is necessary to burn through the fault point of the cable before using the secondary pulse method. Then, a low-voltage pulse is emitted at the moment when the fault point starts to arc, and the pulse is reflected by short circuit at the fault point. After the arc is extinguished, a low-voltage pulse is emitted once again, which passes through the fault to the end of the cable and causes open-circuit reflection [6]. By comparing the waveforms measured by two low-voltage pulses and aligning them with the starting point, it can be found that the wave forms before the cable fault point overlap well, while the waveform curves after the fault point diverge.

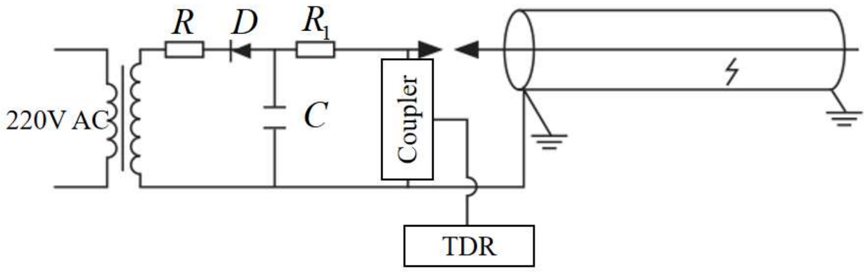

Figure 1 Wiring schematic of improved secondary pulse method

In order to improve the accuracy of locating the cable main insulation fault by the improved secondary pulse method, the metal sheaths at both ends of the cable line should be grounded, the cross interconnection part of the cross interconnection intermediate box should be disassembled, and the metal sheaths at both ends of each phase cable head should be shorted. The modified secondary pulse test wiring is shown in Figure1.

3.2 Theoretical basis

When an applied pulse signal is transmitted from the initial end of the cable to the terminal, it encounters obstacles (impedance mismatch points), which may be the joint of the line or the fracture of the cable, and will reflect a pulse wave back to the initial end. The fault location formula (1) can be obtained:

$$s = \frac{1}{2} v (t_1 - t_0) \tag{1}$$

Volume 7 Issue 12, 2021
DOI: 10.6919/ICJE.202112_7(12).0069

In which s is the distance of fault point, v is the wave velocity of pulse wave in cable medium, t_0 is the time of pulse emission and t_1 is the time of arrival of reflected pulse.

The wave impedance calculation formula of cable is:

$$\rho = \sqrt{\frac{L_0}{C_0}} \tag{2}$$

Where: L_0 is the inductance per unit length of cable and C_0 is the capacitance per unit length of cable.

4. Design of portable cable fault detection device

4.1 Hardware design

(1)Hardware system structure

The working principle of the portable cable fault detection device is shown in Figure 1. The system is mainly composed of the following parts: keyboard circuit, logic judgment circuit, cable detection circuit, LCD display circuit, alarm circuit, data storage circuit and MSP430 single chip microcomputer control system.

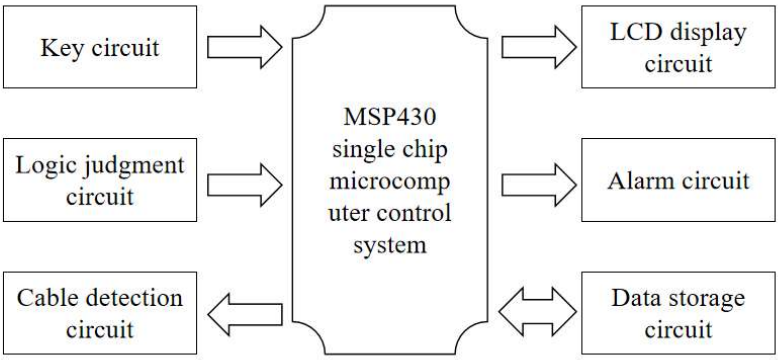

Figure 2 Principle block diagram of portable cable fault detection device

The working voltage of all IC in this system is 3.3V DC. This system designs two test modes; Standard test, custom test.

Standard test:

At first, input the core value through the keyboard, and then enter the cable detection interface. The MSP430 cable detection circuit sends the signal to the logic judgment circuit, which makes judgment, and then sends the judgment result to the MSP430 single chip microcomputer, which sends the data to the storage circuit. After the detection is completed, the data of the data storage circuit is read out for judgment, and the error alarm circuit is turned on and displayed at the same time.

Custom detection:

According to the difference of standard detection, there is no need to input core value for custom detection, and there is no need to worry that one wire corresponds to multiple wires or one wire corresponds to an alarm. Other cables are detected based on the current detection cable. If there is any discrepancy, open the alarm circuit and display the error result.

(2)Design of pulse generating circuit

The pulse generating circuit mainly sends out the pulse signal applied to the cable during the system test, and the key to the design of the pulse generating circuit is that the generated pulse width must be adjustable. Because the pulse width needs to be changed flexibly in this design, a programmable device is used to realize the pulse generation. Variable range devices are used to realize the flexibility and convenience of pulse generation, and the pulse waveform is neat.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202112_7(12).0069

Theoretically, the adjustable range of the pulse width of the pulse generating circuit designed by this scheme is from one programmable clock cycle to N times of clock cycles, and the pulse width can be flexibly adjusted.

(3)Design of pulse receiving circuit

Due to the resistance characteristics of the cable and the corresponding noise interference in the cable, the fault traveling wave signal in the cable will be weakened. If it is less than the sampling resolution, it will be difficult to be collected by the acquisition circuit. Therefore, the transmitted pulse signal also has a great influence on the fault traveling wave signal [7]. Therefore, it is necessary to design a pulse receiving circuit at the sampling circuit point, the main purpose of which is to amplify the fault traveling wave signal and reduce the external interference to the fault traveling wave signal, so as to enable the sampling circuit to collect a complete fault traveling wave signal.

The amplifying circuit is used to amplify the weakened fault traveling wave signal to an appropriate amplitude for the subsequent sampling circuit to collect. At the same time, in order to eliminate the influence of the pulse generating circuit on the amplifier which is the main component of the amplifying circuit, a clamping process is performed before the amplifier, that is, the input of the amplifier is limited.

(4)Generation of clock signal

The generation of detection pulse, the sampling of ADC08100 and the data buffer of asynchronous FIFO constitute a high-speed A/ D data acquisition system. This requires very high time coordination of various signals, which requires a special clock unit to coordinate, so as to make the circuit work under the correct timing.

In FPGA, the clock module can be customized conveniently to generate A/ D sampling clock, read-write clock of asynchronous memory and counting clock of pulse generation module. All clocks are synchronized by a high-speed clock, and the whole system runs synchronously under the same start signal, thus ensuring the sampling timing requirements.

4.2 Software design

(1)Main process design

After the DSP program starts, the clock unit and AD unit of the system should be initialized first. After the initialization of clock and AD units is completed, in order to make sure that CAN communication, reading and writing are normal, self-test is performed, and when the result is normal, then wait for the instruction of the upper computer to be executed.

After receiving the instruction to execute the task, match the host number and the local number in the command. If the matching is consistent, the command will be executed. If it is inconsistent, a second judgment will be made. The second judgment will be made to see if it is the set master command, and the co-tester test flow will be executed according to the set conditions; otherwise, no judgment and task execution will be made. Continue to wait for information from the upper computer. The DSP program flow as shown in Figure 3 is designed.

(2)FPGA development and application

FPGA (Field Programming Gate Array) has the characteristics of high density, high speed, low power consumption and powerful functions. In this system, CycloneII series devices of Altera company are used to realize high-speed data acquisition and storage functions, which are designed by using VHDL in QuartusII 7. 1 software.

The design flow of high-density programmable logic devices includes four steps: design preparation, design input, design processing and device programming, and three design verification processes: functional simulation (pre-simulation), timing simulation (post-simulation) and device testing. This design mainly includes Nios microprocessor, pulse generation, high-speed clock and high-speed data storage FIFO.

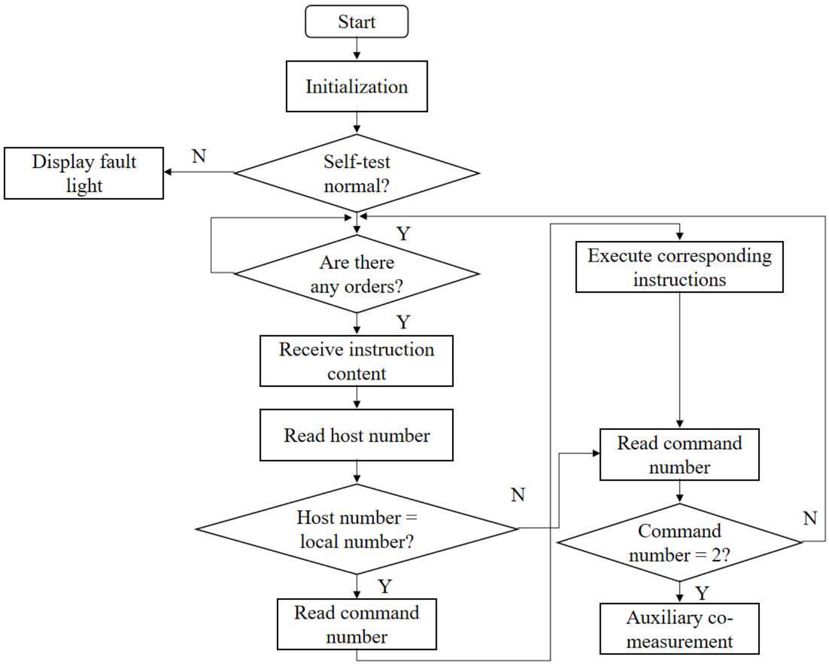

Figure 3 Main program flow of DSP

5. System implementation

In order to explore the accuracy of the improved secondary pulse method and the traditional secondary pulse connection method in measuring the fault of cable main insulation, two tests were carried out according to the scheme in Table 1. During the test, a main insulation short circuit fault was simulated at the terminal of a 110 kV line with power failure.

Table 1 Comparison of test schemes

Positioning method	Grounding mode
Traditional secondary pulse connection mode	Cross interconnection is unchanged, and one end of metal sheath is grounded
Improved secondary pulse method	Cross interconnected metal sheaths are shorted, and the metal sheaths at both ends of the cable are grounded

Traditional secondary pulse wiring is that the wiring mode of the cross interconnection box is unchanged, and one end of the cable metal sheath is grounded. Because the wave impedance of the cable at the cross interconnection is changed, the pulse emission wave becomes complicated, which affects the wave forms at the three joints, and also affects the wave forms at the faults, which interferes with the judgment of the results.

According to the measurement results of the improved secondary pulse positioning method, it can be seen that the fault location is 2.32 km, the ranging error is 6.83%, and the positioning accuracy basically meets the needs of the site. Accurate positioning of cable faults needs to be carried out in cooperation with step voltage method, acousto-magnetic synchronization method, etc.

6. Summary

Combined with the design and development process of portable multifunctional cable fault detection device, this paper studies the whole system including software and hardware system design. The improved secondary pulse positioning method only needs to change the cross interconnection mode of the intermediate grounding box and the grounding mode of the metal sheaths at both ends of the cable when positioning the cable fault in the cross interconnection mode. Powerful, extensible and other advantages, it can be easily applied to the development of various electrical products with a little modification. The application results show that the system is stable and reliable, and has a high degree of automation. The application of automated testing technology can greatly improve the working efficiency and shorten the testing time. It is of great significance to improve the comprehensive maintenance support ability of cable equipment.

Acknowledgments

This work is supported by State Grid Zhejiang Electric Power Co., LTD Innovation Project 5211N121000M.

References

[1] Ge shaowei, Liu Zhe, Hou Jianfeng, et al. experimental study on the accuracy of fault detection device for power cable joints in urban areas [J]. bulletin of science and technology, 2019, 035(002):173-177.

[2] Zhao Changwei, Li Yue. Research on 27.5kV railway intelligent cable and distributed on-line monitoring system [J]. Electrical Technology and Economics, 2019, 8(02):17-20.

[3] He huaimiao. research on fault detection and accurate positioning of power cables [J]. 2021(2011 - 12):183-184.

[4] Zhang Yuanfeng, Hao Shiyong, Zhao Zhibin, et al. Research on troubleshooting training device for typical aircraft electrical system [J]. 2021(2017-14):28-30.

[5] Meng Xiangde. Discussion on the causes and detection technology of power cable faults [J]. Encyclopedia Forum Electronic Journal, 2019, 000(016):399.

[6] Tan Weibin, Zhang Wei, Quan Li, et al. Development of a new online monitoring device for distribution network [J]. Power System Protection and Control, 2019, 47(001):158-165.

[7] Xu Xiaoye, Hu Kewei. Research on fault detection methods and applications of power cables [J]. Mingchenghua, 2019(8):0478-0478.