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Development of Temporary Ground Wire Detection Device

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Abstract

In order to solve the safety problem of disassembling the ground wire temporarily for line maintenance, this paper proposes a new detection method to prevent transmission lines closing with ground wire, and invents a portable detector to detect the status of ground wires by making full use of modern power electronics and digital signal processing technology. Finally this paper developed the corresponding portable ground wire state detector. Descriptions of the use of detector, design ideas of hardware and key algorithms are represented. The detector designed in this paper is simple-operated, low cost, highly reliable, easy to promote, etc. and it also can effectively prevent human-induced accident which is caused by transmission lines closing with ground wire.

Keywords: Ground wire; electric power overhaul; transmission line; boost; comb filter

1. Introduction

Ground wire is important in maintenance and reformations of power systems. At present, it mainly depends on the operation ticket and the performance degree of the operating rules by the operators in the process of transmission line maintenance to avoid the risk. Therefore, there is a high probability of missing-removing the ground wire, which can easily lead to serious accident of 'switch on power transmission with ground'.

The Microcomputer Device avoids misoperation by a series of logic judgment and electric chain and mechanical locks, but for the misoperation behavior of transmission lines closing with ground, which still has serious hidden trouble and security leak [1]. A lot of measures and auxiliary devices have been designed to the management of temporary grounding to avoid closing with a ground wire [2-7]. Ground wire management system can enhance the reliability of using ground wire and regulate the management of ground wire [2-3] by replacing the existing ground wires, but it demands sizable workload and the capital cost. An early-warning system of ground wire state monitoring can timely obtain the working state of ground wire [4], however, there is still no suitable solutions for grounding-switch to avoid accident by human-initiated-failure. Status detecting device of ground wire which has been researched in [5-6] can make power system overhaul work achieve the aim of real time on-line monitoring, but there are some detection defects by using ultrasonic ranging.

These methods and devices play a role in the ground wire misoperation, but most technical methods are based on regulations and human judgment. They need high reconstruction and system building cost, and can't completely avoid the accident by human. Therefore, we should develop a portable intelligent device of ground wire by using the advanced power electronics, signal processing, intelligent decision technique for improving the accuracy and adaptability, and confirm the state of ground wire in technology to prevents the accident of "sending the electricity by closing earth line" effectively.

2. Detection Principle of Ground Wire

In order to ensure the personal safety, there must be ground wire near the ground when someone

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operates with the line, which is specified in the safety operation. Therefore, the design method used by the detector is as following: with the last group detection grounding wires remained and tested, then remove or disconnect the last group after making sure that there is no additional ground wires, which could avoid security risks caused by humans.

2.1. Detection principle of injection voltage

The method of injected voltage measurement is given as figure 1. One end of the signal source of the detection instrument is connected to the ground line directly, and the other end is connected to the earth through the auxiliary pole, which method is simple and practical.

In Fig. 1, the inject voltage used sine wave voltage with adjustable amplitude. In order to avoid the effects of transformer, PT, phase-to-phase capacitance and ground capacitance, and eliminate the interference of induction signal, the writer chose 420 Hz as the working frequency of injected signal according to the results of simulation and practice testing requirements.

It can be seen from Fig. 1 that two ground wires form a loop when there is an additional ground wire and the detected current value I is as the following:

$$I = \frac{U}{R2 + R3 + (RL + jwXL)/3} \tag{1}$$

When there is no additional ground wire, it can't form a loop, and the current $I = 0$. So we can judge the state of ground wire by detecting the current value.

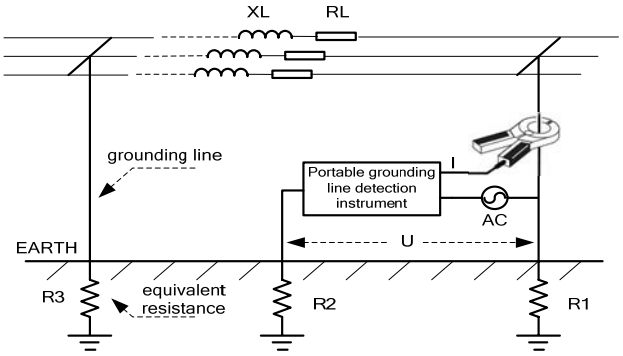

Fig. 1. Schematic diagram of the injected voltage measurement.

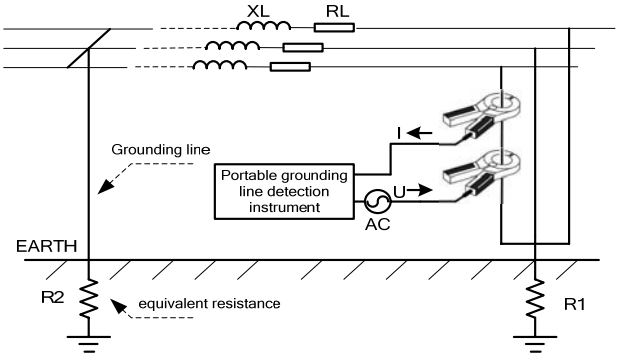

Fig. 2. Schematic diagram for the measurement system of double clamp type.

2.2. Detection principle of double-clamp induction voltage

Double-clamp measurement detects the state of ground wire directly by the judgment whether there are loops between two phases. The specific detection method is as shown in Fig. 2.

When there is a loop, a voltage signal source through the voltage clamp in the measured circuit generates a constant AC voltage. And the voltage in the short circuit loop will generate a current I:

$$I = \frac{U}{RL + jwXL + ((RL + jwXL)/2)//(R_1 + R_2)} \tag{2}$$

Double-clamp detection method eliminates the influence of grounding resistances; it is accurate, convenience and safety.

3. Design of Hardware

3.1. Hardware structure design

According to the detection principle of ground wire, the design of its hardware structure diagram is as shown in Fig. 3. The design of the ground wire detector mainly comprises data processing chip TMS320LF2407, voltage and current sampling circuit, anti-jamming circuit, filter circuit, PWM driving circuit, signal generator, battery power supply monitoring circuit, LCD crystal display and keyboard input circuit.

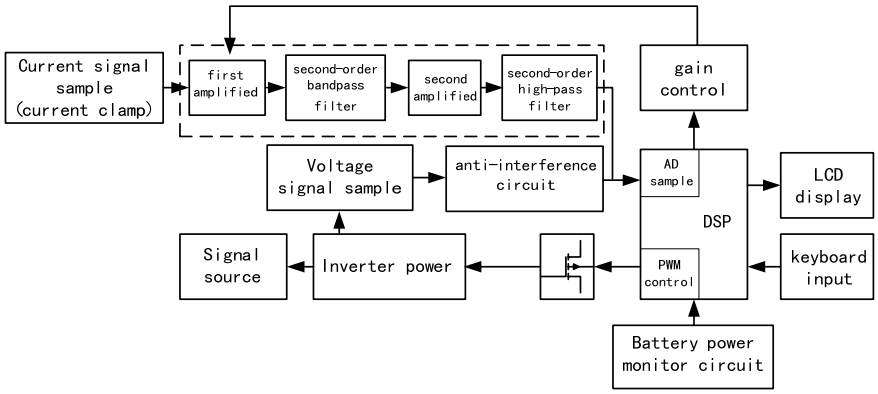

Fig.3. Schematic diagram of hardware structure.

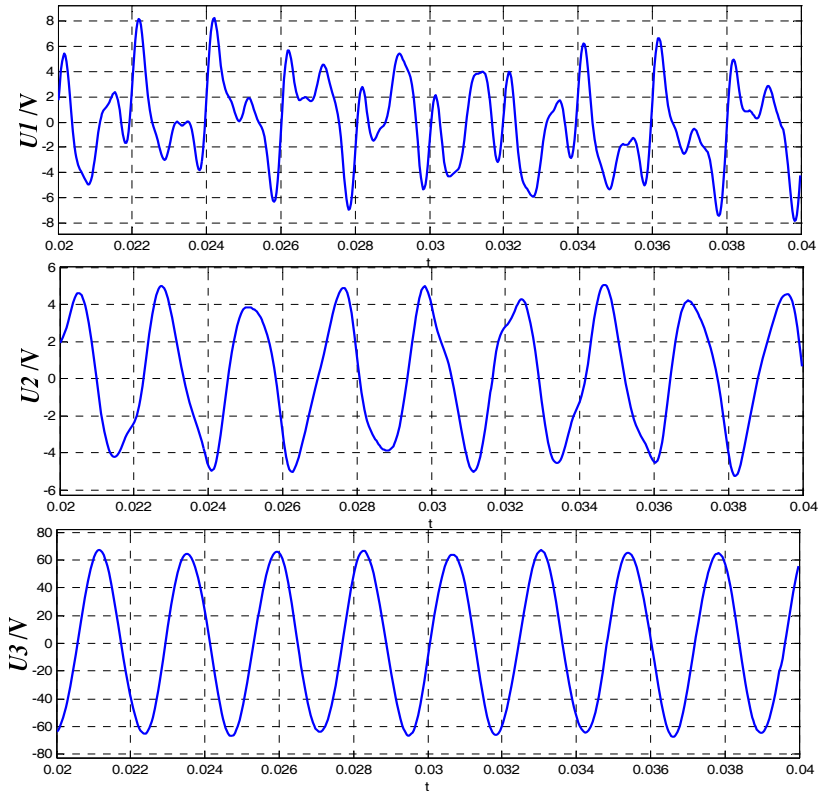

Fig.4. Detection circuit simulation analysis.

3.2. Detection circuit design

The design of detection circuit needs to be obtained from the current sensor, a very weak signal which needs to be amplified to 0-3 V for 10 bit A/D converter for sampling. The accuracy and stability of amplifying and filtering will affect the performance of the detecting device directly. So the preamplifier circuit will use the precision, low power integrated INA118 instrumentation amplifier, and the filter use a two step low-pass, high-pass circuit.

The minimum current value detected is 0.1 mA, and the maximum is 2 A. In order to ensure the accuracy of the measurement, 8 channel digital controlled switch CD4051 is used to control the gain of the amplifier circuit of multiples, realizing the automatic function of switching [7].

In order to verify the circuit's performance, selecting the appropriate circuit parameters, the writer makes the simulation of the circuit as shown in Fig. 4. The input signal *U1* includes interference signals. After two order band-pass filter, the noise components are effectively removed, but the amplitude of the signal is small, the noise ratio does not meet the requirements. So the signal *U2* will be filtered after intermediate amplified. The result of simulation shows that the noise ratio is very high, and it's very beneficial for data processing.

3.3. The design of the signal source

In order to meet the requirements of portable measurement, 6V battery is used as power input by the instrument. Since a 10 V, 10 W standard sine wave signal source is needed, the instrument adopts boost circuit and full bridge inverter technology scheme [8], of which the program structure diagram is as shown in Fig. 5.

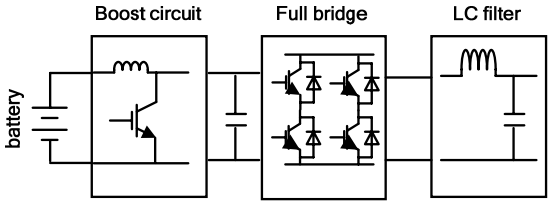

Fig. 5. Schematic diagram of output power.

The design of the Boost circuit changes the input 6 V to 18 V DC voltage, and inverts to a high frequency AC square wave, and finally gets a 10 V RMS standard sine wave through the LC filter circuit. According to the power and the volume requirements, the switch tubes of Boost circuit and the full bridge circuit use AP9971GD which has double MOS transistors. AP9971 is a small volume, with conduction loss, fast switching speed, low cost and small power MOS transistor, of which the voltage and current can reach to 60 V-5 A, on-resistance only 50 m ohm, especially suitable for the system of technical parameters. The MOS transistor driving chip uses high performance full bridge chip IR2110, and this chip is a dual channel. The gate drive, high voltage and high power devices monolithically integrated drive module, greatly simplifying the logic circuit of power device control requirements, improving the reliability of driving circuit. IR2110 has internal bootstrap circuit, with a separate high-end and low-end two output channels, meanwhile it can simultaneously drive the same bridge arm two MOS transistors, and greatly simplify the circuit structure.

4. Detection Algorithm Analysis

After investigation, because of the same induced voltage, there is a power frequency and its harmonics interference signal. Due to the detected current signal is very weak, the interference signal seriously affects the correct determination of the equipment. In order to remove the interference signal component effectively, the detection algorithm uses comb filter and digital filter processing.

Comb filter has the function of enhancing or removing periodic signal component, and its transfer function is as following [9]:

$$H_1(z) = b\frac{1-z^{-N}}{1-\rho z^{-N}}, \quad b = \frac{1+\rho}{2} \tag{3}$$

Its poles are $\rho^{1/N} e^{j2\pi k/N}$, $k = 0,1...,\ N-1$, and its amplitude-frequency response is as shown in Fig.6:

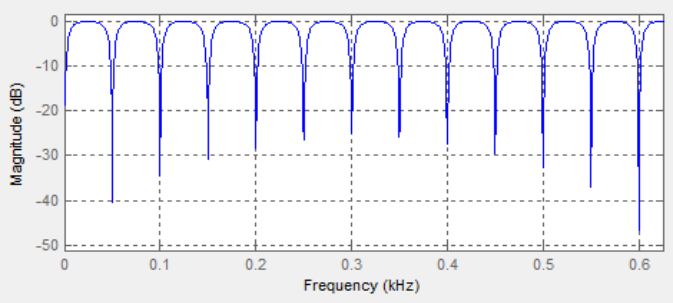

Fig. 6. Amplitude-frequency response of comb filter

From the amplitude-frequency response of comb filter, we can see that it can effectively suppress the power frequency and its harmonics signals, and it's very suitable for the detection of the state of the ground line.

5. Conclusions

This paper introduces the portable ground wire detector's detection method, the key hardware and algorithm design in detail. This instrument inhibits the 'leakage remove ground' accidents by using detection technology. Its advantages are simple and convenient operation, low cost, high reliability, and so on. It doesn't need for high cost of large-scale rectification and it can be easily extended, and matched with other ground wire management system or process. As the last ditch, it eliminates the malignant accident caused by artificial factors, and provides a reliable guarantee for the safe operation of electrical equipment and safety of personnel.

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