Hardware Design of Non-contact Voltage Detector Based on STM32 Microcontroller

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Abstract. In view of the time-consuming and labor-intensive problems of traditional contact electroscopes, this paper designs a hardware system of non-contact voltage detector based on STM32 single-chip microcomputer. The hardware design mainly includes signal amplification and conditioning circuit and power module, Wireless transceiver module, display and alarm module, etc. In order to reduce the distortion of electric field caused by human during measurement, a wireless transceiver module device is adopted, which has a simple structure and can meet the engineering requirements of the non-contact power inspection of the transmission line.

1. Introduction

Transmission lines are main parts of the power system and the main means of power transmission. The safe operation of transmission lines plays a decisive role in the power grid structure and operation of the power system. With the continuous expansion of the power system, in order to maintain the safe operation of transmission lines, maintenance operations are facing more serious problems. High voltage transmission line must be power off before the maintenance crews maintaining lines, or the maintenance crews are facing life-threatening crisis. [1] In order to solve the problem of time wasting and low security in traditional contact voltage detector, a hardware system of non-contact voltage detector based on STM32 single-chip microcomputer is designed in this paper. It can detect whether or not the transmission lines are charged over a long distance and non-contact. It can also determine the three-phase transmission line charged state based on multi-point measurement data, and issued a corresponding sound and light alarm signal.

2. Overall system design

This paper designs a portable device that can detect the variation of induced voltage under high-voltage transmission lines, and judges the running state of high-voltage transmission lines through reasonable analysis. Its main function including: (1) being able to detect the induced voltage value under the high voltage transmission line and transmitting the signal through the wireless transmitting module; (2) the wireless receiving module can correctly receive the data transmitted by the transmitting module and display it; (3) can detect according to the detecting The magnitude of the voltage value determines whether the transmission line is energized and sends a corresponding audible and visual alarm indication; (4) It can judge the on-off condition of the three-phase transmission line of the high-voltage transmission line by measuring the multi-point. In addition, the system has the characteristics of low cost, small size, easy to carry, easy to operate, and high reliability. [2] The overall block diagram of the non-contact voltage detector is shown in Figure 1.
The parallel plate transmits the AC voltage across the measured capacitance to the main circuit board through the signal lead. First, the amplification voltage and the voltage extraction circuit are used to convert the high voltage AC into DC, and the analogy signal collected by the A/D module built in the STM32. It is converted into a digital signal, and then the measured voltage is converted into an actual induced voltage inside the microcontroller, and finally the actual value of the voltage is transmitted through the wireless transmitting module.

3. System tough guy design

Hardware design is an important part of the system and the key to the entire system. The hardware circuit mainly realizes functions such as amplification filtering, acquisition, signal transmission, reception and analysis, result display and alarm for the power frequency electric field signal. Based on the above-mentioned overall system architecture, the following focuses on the design of several key parts in the system hardware design.

3.1. Signal conditioning circuit

After the electric field sensor obtains the electrical signal, it is transmitted to the analog-to-digital conversion channel of the single-chip microcomputer through the signal conditioning circuit. The design of the signal conditioning circuit needs to implement three functions: (1) the initial amplification of the original signal, because the signal of the sensor is very weak during the actual detection process, only the millivolt level; (2) the signal is filtered and processed. In the process, due to the influence of the test environment, it is necessary to filter out signals other than the power frequency; (3) the signal needs to be conditioned to meet the unipolar voltage signal of the sampling range of the AD conversion module in the main control chip.

3.1.1. Preamplifier circuit

Figure 2. Differential preamplifier circuit
In the differential amplifier circuit, \( C_1 \) is the external measurement input capacitance, \( R_3 \) is the input impedance of the matching sensor. Since the sinusoidal signal detected by the system is a floating power supply, in order to avoid the influence of the input bias current, it is necessary to add a resistor \( R_1 \), \( R_2 \) at the input end to have a DC path for the input and ground. \( R_g \) is used to adjust the gain of the AD620AN with the formula:

\[
A_1 = \frac{49.4K\Omega}{R_g} + 1
\]  

(1)

In the formula, \( R_g \) is an adjustable resistor, and the differential induced voltage value is controlled within the voltage range that the AD can collect by adjusting \( R_g \) at different voltage levels.

3.1.2. Second stage amplification filter circuit

![Figure 3. Amplifying and filtering circuits](image)

In Figure 3, \( R_4 = R_5 = 100k \), \( R_6 = 1M \), \( C_2 = 2200pF \). When the acquisition signal is low frequency signal, the low-pass cutoff frequency can be set according to the collected signal. The circuit adopts a RC configuration to set the cutoff frequency as:

\[
f_p = \frac{1}{2\pi R_2 C_2} = 72.38Hz
\]  

(2)

The RC configuration is fully satisfied with the filtering function of this design. Magnification can be matched according to actual needs, the magnification of the circuit set here:

\[
A_2 = 1 + \frac{R_6}{R_4} = 11
\]  

(3)

3.1.3. Voltage boost circuit

Since the signal collected by the high voltage sensor of the voltage detector is an AC voltage signal, and the allowable sampling range of the AD conversion module in the STM32 chip of the system is 0 to 3.3V, the input signal must be a DC voltage signal, so the signal is collected by the sensor. After passing through the signal amplification module and the signal filtering module, the signal must pass through the voltage boosting circuit before being transmitted to the signal acquisition module of the main control chip, so that it becomes a DC signal, and can be recognized by the analog-to-digital converter. Therefore, the input signal is raised by the adder to a unipolar voltage signal based on 1.5V, and the DC bias voltage is obtained by dividing the 5V power supply by an adjustable resistor. The designed voltage boost circuit is shown in Figure 4.

![Figure 4. Voltage-boosting circuit](image)

3.2. Power module

The system power module is mainly divided into three parts. The first part of the amplifier power supply is powered by a 12V lithium battery through a voltage conversion module to positive and negative 5V to the amplifier, and the second part is a system circuit power supply voltage source for
chip power supply in the circuit; The third part is a precision reference voltage source that provides the reference voltage for AD conversion.

The system includes digital circuit parts as well as analog circuit parts, so the power supply system must be designed with full consideration of the two parts of the power supply requirements in Figure 5, 6.

![Figure 5. Series feedback voltage stabilizer circuit](image1)

![Figure 6. The reference voltage source that is formed by OP amps](image2)

The three-terminal integrated low-dropout regulator chip CAT6219-3V3 is selected to form a voltage regulator circuit, and the reference voltage source analogy integrated chip TL431 is used to obtain a high-precision and high-stability reference voltage source. The power module circuit designed in this paper is shown in Figure 7: CAT6219 converts 5V to 3.3V to supply power to the system, and adds decoupling capacitors to the input and output terminals to improve the anti-interference ability of the device against power supply noise and reduce current interference. The TL431 can be used to provide a stable reference voltage to the AD. The capacitors C5 and C6 in the circuit are filter capacitors to achieve high frequency and low frequency filtering.

![Figure 7. Power module circuit](image3)

3.3. Wireless transceiver module

When the operator performs voltage detection under the transmission line, the human body has a more obvious influence on the electric field, which will cause distortion of the surrounding electric field and have a greater influence on the induced voltage between the plates, so in order to eliminate the influence of the human body on the electric field around the voltage detector, to reduce the voltage measurement error of the non-contact voltage detector in the high voltage electric field, the system uses a short-range wireless transceiver module to measure the induced voltage value.

The short-range wireless receiving and transmitting module is mainly composed of wireless data transmission and wireless data receiving, and its data transmission diagram is shown in Figure 8. The MCU sends the data to the CC1101, and then transmits it through the antenna. The receiving end receives the data through the antenna for processing, and obtains the correct and verified accurate data, which is then transmitted to the MCU.
3.4. Display and alarm module

When the line is overhauled on a transmission line under a certain voltage level, if the induced voltage is lower than the field induced voltage value set in the system, it means that the work place meets the standard and the operator is safe. If at this time, the buzzer will not alarm. If the induced voltage exceeds the limit, the buzzer will immediately alarm, warning the maintenance personnel not to be close to the transmission line, thus avoiding the occurrence of electric shock.

3.4.1. Display module

The OLED module with the driver chip as SSD1306 is selected with a friendly interface and clear and clear display output conversion results. OLED has the advantages of small size, high resolution, wide viewing angle, light-emitting by the pixel itself without backlight, low power consumption, long life, wide dynamic range, flexibility and normal operation under low temperature conditions. The display of the OLED screen is controlled by SSD1306 and STM32F103C8T6 through D0, D1, D/C, RES, and the like. In SPI mode, only 4 wires are needed to communicate with the controller, which is more suitable for the system.

3.4.2. Sound and light alarm module

Designed for the sound and light alarm module. Ordinary LEDs cannot be clearly observed in daylight, so the visual indication uses high-brightness LEDs for easy judgment and observation by the operator. The buzzer uses a piezoelectric buzzer, which is mainly composed of a piezoelectric ceramic and an oscillating circuit, and also includes an impedance matching device and a resonance box thereof. The driving circuit diagram is shown in Figure 9. When the MCU gives it a low level, the multivibrator starts to oscillate and outputs an audio signal. The impedance matching device pushes the piezoelectric buzzer to sound.

3.5. PCB board design

PCB board is very important, because compared to electronic products, to make the circuit schematic into a specific product, circuit board design is the only way, whether the circuit board design is reasonable and closely related to the production and quality of the product. If the board design process is unreasonable, the performance of the designed product will be greatly reduced, and the life is reduced. In the case of serious intermittent failure, it will not work properly. Therefore, we must attach great importance to the design of the PCB board. When designing a PCB board, special attention should be paid to the layout and routing of components, as it has a large impact on the life and stability of the board. The final design of the PCB and the soldered circuit board are shown in Figure 10.
4. Conclusion

This paper firstly describes the overall design of the voltage detector system. Secondly, it mainly designs the selection of signal processing circuit modules, power modules, wireless transmission modules, display and alarm modules, and PCB circuit board design, which together form the hardware circuit part of a non-contact voltage detector. The principle of function stability is selected by comparison to design each module: the power module selects the design of the system power supply and the AD precision reference power through the different advantages and disadvantages of the different power supply design of the design method; signal processing The selection of the module amplifier is also a key link. The precision amplifier is required to amplify the signal and the advantages of the active filter circuit. The display alarm module analyzes and compares several commonly used display devices and selects and designs them circuit according to the requirements of the voltage detector. PCB layout process should pay attention to the overall layout and wiring rules, pay special attention to the power line, ground line width and input and output signal lines to avoid parallel and so on.

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