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Design of grounding wire with remote electrical testing function

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Abstract

In the process of power production, it is necessary to strictly implement the work steps of "power cut" - "power inspection" - "grounding" and implement safety measures. However, in actual operation, other human factors may lead to live installation of grounding wire, which may cause electric shock personal safety accidents. Therefore, STM32F103C8T6 micro-controller is used to design a kind of adjustable grounding wire with electrical testing distance, which can provide real-time audible and visual alarm when connecting wires without electrical testing. Through on-site testing, the equipment can achieve the purpose of remote detection in different electromagnetic environments.

Keywords

Grounding wire; Remote electricity inspection; Prototype development.

1. Introduction

In the process of electric power production, it is necessary to strictly follow the working steps of "power failure" - "power inspection" - "hanging and grounding", and implement safety measures. But in the actual work site, there are two safety risks: 1, because the staff careless forget to check the electricity and directly install the grounding wire, there is a risk of live installation wire.2. In the gap between the power inspection and the installation of the grounding wire, the line suddenly calls up due to misoperation or other reasons, and the staff installing the grounding wire does not know and directly install the grounding wire, leading to the installation of the live grounding wire and causing the personal safety accident of electric shock. Therefore, it is necessary to design and make a grounding wire with power inspection function. When the grounding wire is hung close to the charged body, a sound and light alarm can be issued to timely remind the staff to stop the grounding wire installation immediately, so as to avoid the charged installation of the grounding wire and improve the working safety.In the process of designing the grounding wire with the function of electricity inspection, the technical core is remote electricity inspection. The basic principle of remote electricity inspection is proposed in the document [1-2]. On this basis, the design and implementation of the alarm distance adjustable grounding wire is proposed in this paper.

2. Design principle

In the power system analysis, the distribution line can be regarded as a cylinder. Considering its axisymmetric characteristics and ignoring its axial electric field, for any distribution line, a is the conductor radius, r is the position vector from the source point to the field point, and E (r, t) is the electric field strength at the field point P. According to relevant theoretical knowledge, it is deduced that the electric field strength near the conductor has the following relationship with the conductor voltage:

$$E(r,t) = \frac{a}{r^2} V_0(t) \cdot e_r \tag{1}$$

Where is the unit vector from the source point to the field point, and is the known conductor potential. It can be seen from the formula that when the distance r is fixed, the electric field strength in the vicinity is linearly related to the wire voltage; when the conductor potential is fixed, the electric field strength is inversely proportional to the square of the distance r. When the electroscope based on the electric field sensor is used for electrical inspection, if the conductor is charged, the electroscope will gradually close to the conductor, and the amplitude of the induced voltage of the electric field sensor will also increase. When it is greater than the preset threshold voltage of the electroscope, the electroscope will send an alarm prompt to realize electrical inspection.

According to the actual operating experience of power systems, 10kV transmission lines can be divided into two modes: single-phase conductor mode and three-phase horizontal arrangement mode. The following is a simulation for both cases

(1) Single-phase conductor model

As shown in Figure 1, the cross section of the single phase 10kV distribution conductor model. According to the actual situation of the distribution line, the conductor adopts aluminum stranded wire with a cross section of 120mm2, a radius of 6.17mm, and the distribution conductor is 10m from the ground. Since the peak phase voltage of 10kV distribution line is 8.17kV, the excitation voltage of 8.17kV is applied to the conductor model.

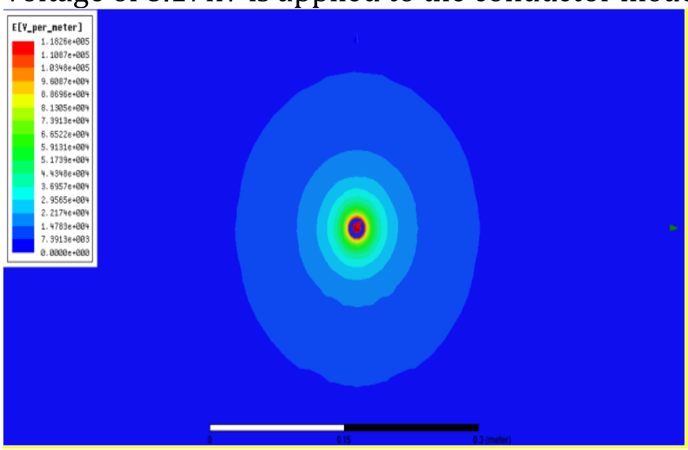

Fig.1 Electric field distribution of single-phase 10kV distribution line

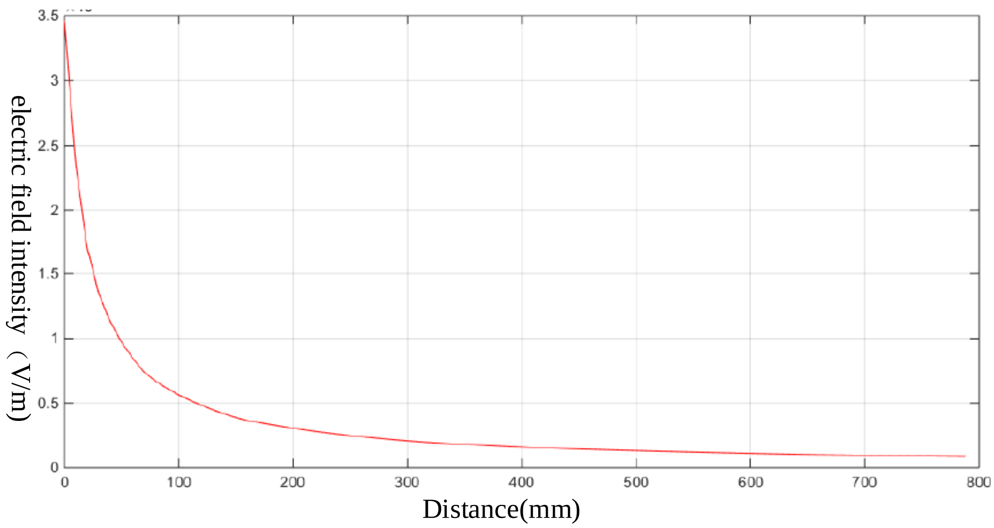

Fig.2 Vertical electric field distribution of single-phase 10kV distribution line

The electric field simulation of the single-phase 10kV conductor model in Figure 1 shows the electric field distribution diagram. It can be seen from the figure that the high electric field intensity is mainly distributed near the conductor, and the electric field attenuation is obvious

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when the distance increases. The electric field analysis is carried out on the path 0.8m vertically downward from the center of the circle of the single-phase conductor section, and the electric field intensity change curve shown in Figure.2 can be obtained. From the figure, the change law of the electric field intensity with the distance presents a negative quadratic power function relationship, and the electric field decays faster with the distance. At 0.7m away from the distribution line, the electric field intensity has been reduced to 960V/m.

(2) three-phase horizontal arrangement mode

The simulation model of horizontal arrangement of three-phase 10kV conductors is shown in Figure 3. The three-phase conductors are horizontally arranged, with a radius of 6.17mm, a distance between phases of 0.7m, and a distance of 10m from the ground. The voltages applied by the three-phase conductors are:

$$\begin{aligned} \dot{U}_A &= 8.17\angle 120^0 kV \\ \dot{U}_B &= 8.17\angle 0^0 kV \\ \dot{U}_A &= 8.17\angle -120^0 kV \end{aligned} \qquad (2)$$

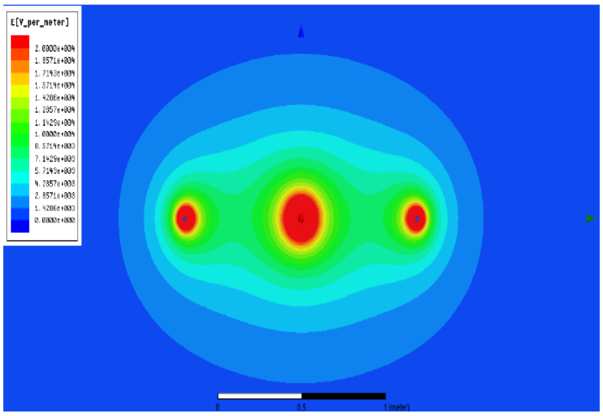

Fig.3 Electric Field Distribution of Single-phase 10kV Distribution Line

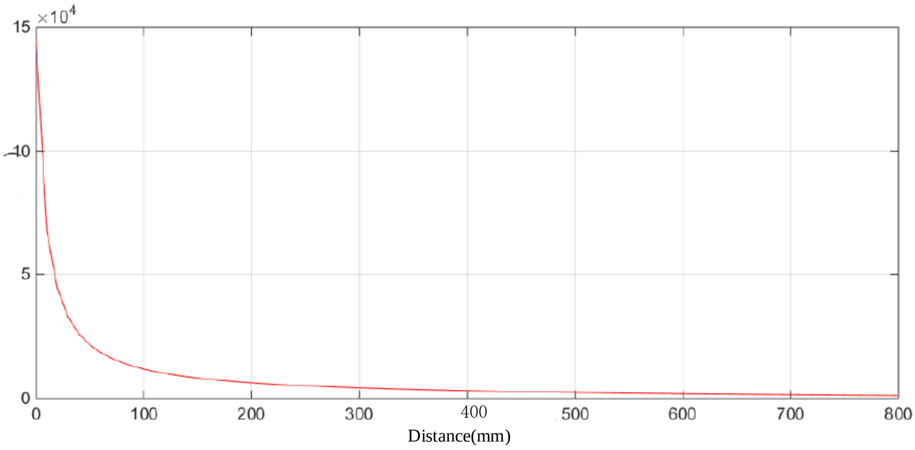

Fig.4 Vertical electric field variation curve of three-phase 10kV distribution line

Carry out electric field simulation on the model shown in Figure 4, and get the electric field distribution diagram of three-phase 10kV distribution line . According to the figure 4, the electric field intensity near the middle phase conductor is significantly higher than that near the other two phase conductors. In order to facilitate observation and analysis, carry out electric field analysis on the phase B distribution line with higher electric field intensity. At a distance of 0.7m from phase B distribution line, the electric field intensity attenuates to 1749V/m.

According to the electric field change rules under the above two distribution line models, it is summarized as follows:

(1) Under the vertical distance of the two distribution line models, the change rule of the electric field intensity with the distance is consistent, and the electric field intensity is close to the inverse quadratic relationship with the distance;

(2) Although the electric field distribution rules under the two distribution line models are consistent, the electric field intensity at the same distance is not consistent, and there is a certain gap.

Therefore, the non-contact electrical inspection using the induced voltage of the electric field sensor can not judge the accurate distance information according to the measured electric field intensity, but can judge the approximate change trend of the distance according to the change law of the electric field intensity, so as to achieve the effect of warning.

According to the design requirements of the project, a kind of grounding wire with the function of electricity inspection is mainly divided into two parts; The grounding wire and non-contact electroscope, of which the non-contact electroscope is the design core of this subject, mainly including the following three parts: electric field sensor, signal conditioning circuit, and processor. The principle structure of electric field sensor is shown in Figure 5:

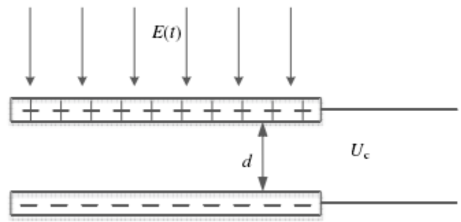

Fig.5 Schematic structure diagram of electric field sensor

Because the distance between the two parallel plates is short, the material and size of the plates are the same, and the plates are composed of weakly conductive dielectric, so the plate capacitive electric field sensor is equivalent to a capacitor. The charge induced by the upper and lower plates can be regarded as equal and different, and the induced voltage of the electric field sensor is Uc (t). When the electric field is applied, the magnitude of the induced voltage Uc (t) output by the plate capacitive electric field sensor is linearly related to the electric field strength E (t), and the proportional coefficient is k. The electric field strength can be obtained by measuring the induced voltage. The induced voltage of the non-contact electric field sensor is sent to the ADC1 port of the STM32 single chip microcomputer after being processed by the step-down circuit, the voltage follower circuit, the second-order low-pass filter circuit and the precision rectification circuit, and the buzzer is driven by the regular program to achieve the purpose of alarm.

3. Hardware circuit design

As shown in Figure 6, the partial voltage limiting circuit and the voltage follower circuit of the induced voltage reduce the input induced voltage to the range that can be read by the single chip computer. The partial voltage ratio is 6.2:1. The voltage follower uses the characteristics of high input impedance and low output impedance to match the impedance and improve the load capacity. Figure 7 shows the second-order low-pass filter circuit. Because the substation has a very complex electromagnetic environment, corona discharge and switch opening and closing phenomena will release a large number of high-frequency clutter signals, which need to be filtered out. Compared with the passive filter circuit, the active second-order low-pass filter circuit has the advantages of steeper amplitude frequency characteristics and better filtering effect, because STM32 can only read positive voltage, Therefore, the dual-power precision rectification circuit shown in Figure 8 is also required to rectify the sine voltage. The rectified voltage meets the STM32 reading requirements. The traditional bridge rectifier can only rectify the voltage signal that is more than twice the diode turn-on voltage drop. It cannot meet the rectification requirements for weak signals, which will seriously affect the accuracy of voltage detection. Compared with the bridge rectifier circuit, The precise rectification circuit can rectify the weak mV voltage signal.

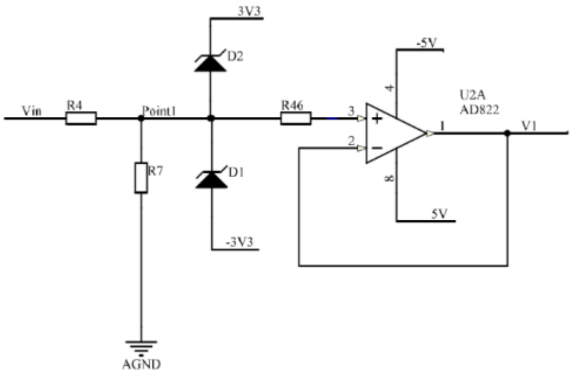

Fig.6 Voltage dividing and voltage following circuit

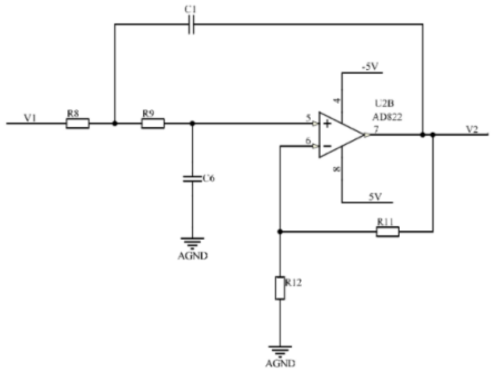

Fig.7 Low-pass filter circuit

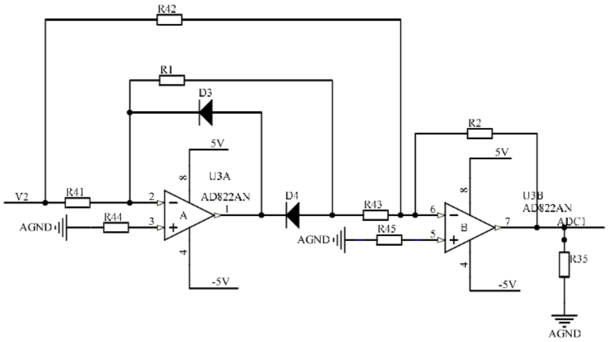

Fig.8 Precision Rectifier Circuits

According to the actual use experience of tools and instruments, the electroscope should conduct self-inspection before use to verify the normal operation of the circuits and program functions of each part of the electroscope. The self-inspection circuit is shown in Figure 9. The self-inspection function is realized by hardware circuit and software program. After the electroscope is turned on, press self-inspection to conduct self-inspection. At the beginning of self-inspection, the single-chip computer will first_ The con terminal is set to high level, Q2 is on, and V1 terminal outputs 5V voltage. V1 is applied to the signal input terminal Vin of the non-contact electrical testing circuit. When STM32 detects the normal operation of the non-contact electrical testing circuit through ADC1, it outputs a 2Hz audible and visual alarm signal lasting for 2s to indicate that the electrical testing self-test is being carried out.

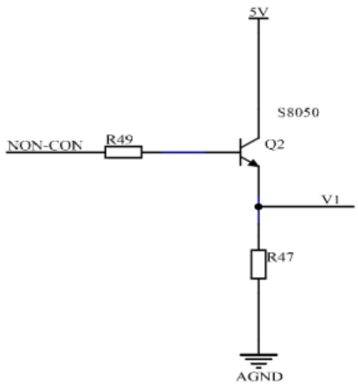

Fig.9 Self Test Circuit Design

4. Experimental results and Conclusion

Fig. 10 Remote electricity test

Using the high voltage test platform as shown in Figure 10, boost the AC voltage source to 10 kV, vertically close the electroscope probe to the 10 kV conductor, and observe the state of the electroscope at 0.8 m, 0.7 m, 0.6 m, 0.5 m, 0.4 m, 0.3 m, 0.2 m and 0.1 m from the probe to the conductor.

Table 1 Remote electricity test

distance(m)	0.8	0.7	0.6	0.5	0.4	0.3
Alarm or not	×	√	√	√	√	√

Table 1 shows the state of the electroscope at different distances. It can be seen from the chart that the change of voltage with distance conforms to the change of electric field strength with distance, so it is feasible to use the induced voltage to judge the distance between the electroscope and the charged body. It can be seen from literature [21] that the safe distance between the staff and the 10 kV live equipment is 0.7 m, so it is only necessary to set the induced voltage at the safe distance of 0.7 m as the alarm starting voltage, and set different frequency alarm signals at different voltages to realize non-contact alarm and judge the distance between the detector and the live body. According to the actual measurement, the alarm effect of non-contact electricity inspection is good, and the alarm is sensitive at the safe distance. With the decrease of the distance, the alarm frequency also increases, which can effectively remind the maintenance personnel of the distance from the charged body.

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