Research on intelligent near-power early warning system for mechanical vehicles

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Abstract. Base on the electric field strength measurement technology, an early warning system for a mechanical vehicle close to a high voltage electric wire is studied. By analyzing the influence of the distorted electric field, the correction matrix of the probe is obtained by comparing the standard value with the measured value, which greatly improves the correction matrix and the accuracy of the alarm. Through the signal conditioning at the signal collector, the data comparison judgment is realized.

1. Preference
With the development of scientific and technological productivity and the improvement of modern industrialization, the scale of power grid construction has been changing with each passing day. Although power has brought a lot of convenience to people's life production, its own potential harm cannot be ignored. Since the emergence of high-voltage electricity, electric shock accidents have occurred frequently, especially the electric shock trip accident caused by mechanical construction is not uncommon. In order to effectively realize the near-power early warning function of high-voltage transmission line mechanical vehicles, the detection of transmission cables, the monitoring of electric field strength, and the ranging alarm of high-voltage transmission lines are all issues to be considered.

At present, the mainstream methods and ideas for dealing with this problem mainly focus on near-inductive cable detection, image recognition, power line laser ranging, radar system high-voltage line ranging, etc. [1].

The near-inductive charge detection electric field uses an induction component to sense the electric field signal in the space. An electric field band composed of charged particles is formed around the AC high-voltage transmission line, and the electric field is stronger as it is closer to the transmission line. Using this principle, the literature [2] achieves the monitoring of the electric field alarm and the distance of the high-voltage transmission line by detecting the electric field change formed on the cable by the wire rope cutting the magnetic field line. Mechanical vehicle electric shock can also be solved by infrared detection image recognition technology.

The literature [3] performs block processing on the collected image, and enhances the contrast between the measured target and the background through technical means, and fits the horizontal power line by computer simulation. In the literature [4], the laser signal emitted by the laser emitter is reflected by the rotation of the polyhedral prism into a fan beam surface laser signal. The emitted fan
beam laser can cover the high voltage cable within a certain range, so this increases the ability to automatically evade slender obstacles. In the literature [5], the method of radar ranging can identify cables with a diameter of 10 mm, and the detection distance can reach 300-900 m, and the recognition rate can reach 99.5%. Image recognition, laser ranging and radar systems can achieve cable identification, but it is difficult to achieve low cost and easy to use. The method of near-induction is simple in system structure, low in cost but poor in accuracy [6]. In this paper, the measurement principle of spherical sensor is analyzed, the source of measurement error is pointed out, and the influence of distortion electric field is studied. By comparing the standard value with the measured value, the correction matrix of the probe is obtained, which greatly improves the accuracy of measurement. On this basis, a mechanical vehicle near-electrical early warning system with low cost, simple installation and no influence on construction operation has been developed.

2. Spherical sensor measurement principle

The electric field strength measuring sensor uses a spherical sensor, which has the advantage of simple structure, convenient design and accurate measurement. The one-dimensional spherical electric field probe is a two metal hemispherical shell connected by a hollow insulating material, which is equivalent to a capacitance sensor. The housing is two stages of capacitance, and the insulating material is a capacitance medium, as shown in figure 2.1. At this time, as long as a capacitor is connected between the two poles to act as a measuring capacitor, a voltage is formed between the measuring capacitors due to the induced charge. This can be used to reflect the intensity information of the spatial electric field [7].

Under ideal conditions, the spherical probe is placed in a uniform electrostatic field electric field, and the position of the center of the sphere is recorded as O point. Under the electric field of the spherical probe, the surface generates an induced charge. Assuming that the upper shell surface area is S, the induced charge density of the surface is set to $\sigma(t)$.

![Figure 2.1. Schematic diagram of one-dimensional spherical sensor probe.](image)

The amount of induced charge in the hemispherical shell is:

$$Q(t) = \int \sigma(t) dS$$  \hspace{1cm} (2.1)

The related literature proves that the amount of induced charge $Q(t)$ generated by the spherical probe in the electric field is proportional to the electric field strength $E_u(t)$ at the O point of the spherical center:

$$Q(t) = k E_u(t)$$  \hspace{1cm} (2.2)

Where $k$ is the proportionality factor. Because the upper and lower housings induce charge, a voltage difference is formed in the measurement capacitor $C_m$.

$$U_m(t) = KE_u(t)$$  \hspace{1cm} (2.3)

Substitute (2.2) is available:
It can be seen from (2.4) that the electric field strength \( E_u(t) \) at which the center of the ball is located can be obtained by measuring the voltage difference \( U_m(t) \) between the capacitance \( C_m \). This is the theoretical principle of measurement of spherical sensors.

3. Research on near-power early warning sensor

3.1. Spherical sensor measurement principle

In the measurement principle of spherical electric field sensor, the spherical electric field measuring sensor is designed in this test system, as shown in figure 3.1. The probe of the electric field sensor utilizes a voltage value converted by a capacitance generated between corresponding electrodes in a space electric field. Then, the electric field strength is measured by calculating the correspondence between the voltage and the field strength.

![Figure 3.1. 3D spherical probe making physical map.](image)

3.2. Near-power warning sensor calibration

In order to adjust and calibrate the accuracy and sensitivity of a spherical electric field sensor, a uniform electric field of known size and adjustable intensity is required for testing. The electric field is formed between two aluminum plates with a length and width of 1 m and a thickness of 2.5 mm. Transient uniform electric field can be generated between the electrodes of the two aluminum plates.

During the development of the spherical electric field device, the test capacitors with different capacitance values were tried. After trying different magnifications, the experimental requirements were met when the magnification was 1000 times. The standard electric field strength is measured by the conditioning circuit, and the electric field strength of the standard electric field has been calibrated by the electric field meter. The measured capacitance result is converted into an electric field value through a one-dimensional voltage value, and the final synthesized electric field value is obtained by a three-dimensional electric field synthesis formula to facilitate comparison.

The calibration result is shown in the line graph shown in figure 3.2. It can be seen intuitively that the measured value of the measured capacitance cannot be measured normally, and the measured value cannot be sensed. In 0pF, 120pF, 220pF and 560pF, the measured values of 300pF are the highest, and there is no result exceeds range. Finally, 300pF is selected as the measurement error of the spherical electric field.
Figure 3.2. Measured value U(V) line graph corresponding to different Cm values.

The calculated residual standard deviation is 0.090, which is the best linearity of the measured capacitance for all different capacitance values.

4. Mechanical vehicle near-power early warning system design

The system is equipped with an infinite communication module, a GPS positioning module and a short message communication module to provide the monitoring station with the location status and data of the dangerous area workers in real time. The signal acquisition module collects the electric field intensity signal through the spherical sensor and performs amplification filtering treatment. Then, the 50Hz power frequency electric field intensity signal is extracted, passed into MCU and compared with the AD conversion. If the electric field strength is greater than the set comparison threshold, an alarm signal is sent back to the communication alarm device. After receiving the signal, the communication alarm device will alarm to indicate that the user equipment is close to strong power. At the same time, the position coordinates of the time are collected by the GPS module, and sent to the supervisor's mobile phone through the short message sending module.

The mechanical vehicle early warning system designed the function of three-speed alarm sensitivity and boundary alarm according to the actual needs of the construction environment. Through the hardware button control and software program to achieve three-speed sensitivity, each file sensitivity has a comparison of the electric field strength, the construction personnel to set according to actual needs. The composition of the near-power early warning system is shown in figure 4.1.

Figure 4.1. Mechanical vehicle near-power system function composition diagram.
5. Software design of near-power early warning system

In order to meet the requirements of the mechanical vehicle near-power system, combined with the design of the hardware circuit, the software is also divided into a signal acquisition part and an alarm communication part. Signal acquisition mainly implements functions such as data acquisition and processing and data transmission. The alarm communication part includes data transmission, GPS information reading processing, short information data transmission, voice module execution, and boundary alarm program design. The overall flow chart is shown in figure 5.1.

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Figure 5.1. Software function design flow chart.
6. Conclusion

(1) By studying the measurement principle of spherical sensor and analyzing the source of its measurement error, it is proved that the error of the measurement result of the spherical sensor is negligible, and the three-dimensional probe can compensate the error when the measurement direction of the probe is inconsistent with the direction of the power line. The electric field distortion caused by the probe can be compensated by the correction matrix, and the correction parameters of the spherical electric field sensor probe are calculated by experimental data.

(2) The mechanical vehicle near-power early warning system has designed three alarm sensitivity and boundary alarm according to the actual needs of the construction environment. The boundary alarm can be analogized to a self-learning type alarm. By pressing the button, the electric field strength of the signal acquisition end can be collected and set to compare the threshold value. If the next time near the same electric field strength, the alarm device will perform a voice alarm.

(3) The system is divided into a signal acquisition terminal and a communication alarm terminal, and data transmission is performed between the two through the NRF905 wireless module. Both modules use the PIC18F87K22 series MCU. The signal collector focuses on signal conditioning, and the MCU realizes data comparison judgment. The communication alarm terminal integrates several modules of wireless communication, voice alarm, GPS positioning, SMS communication and mechanical vehicle emergency braking.

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