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A New-type Safety Warning Equipment for Electric Power System

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Abstract—The electric power system has the features of complexity and risk. When operating, workers often go into charged areas, touching charged equipment. That is dangerous. So this paper describes a personnel safety warning equipment for electric power system. The equipment not only provides safety warning, but also shows the location of the workers to the supervisor. The device is mainly divided into positioning base stations and electric field intensity measurement module. When the workers wear the warning device and nearing into a dangerous area, the device will sound warning, alert workers retreat from the site. In addition, the warning device can also show the real-time position of workers that facilitate supervisors to grasp the safety situation of workers and take appropriate measures. This safety warning device can guarantee personal safety and has the good economic effect.

Keywords—electric field intensity; location; dangerous area; UWB

I. INTRODUCTION

Due to the complexity and danger of power on-site operation, ensuring environment safety is crucial work because of it related to personal safety and proper functioning of electrical equipment. Power workers should be equipped with a special guardian in the electrified environment and the guardian must perform the monitoring without interruption. If the guardian found the workers improperly operating or approaching to the high voltage equipment, must correct them in time. If the site is a relatively complicated working environment, should consider adding guardians. However, in the actual construction, the workers are not able to strictly follow the prescribed construction due to a lot of objective and subjective factors, such as the external environment, workers thoughtless and there will be inevitable safety distance error, etc. Besides, due to on-site environment is complex or the workload is large, guardians cannot completely monitor workers and on-site environment, result in failure to prevent security risks.

Based on the above analysis, in order to ensure workers' personal safety, one reliable and effective strategy is using a device to avoid approaching the high-voltage equipment, and real-time display of workers' location. Because the direct cause of injury to the human body is that the ambient electric field intensity exceeds the specified safety range of the body. By measuring the electric field intensity around the workers, we can warn when the strength exceeds the safety range. At the same time, considering the need of monitoring workers, we can real-time positioning workers using the UWB technology. In addition, using the measured data, we can draw the dangerous area map as reference information on the computers.

II. RELATED WORKS

At present, there are many advanced devices about measuring the electric field. However, the device is expensive or the effect of solving above problems is not obvious. For example, the V-Watch Personal Voltage Detector of the US HDE company will give warning sound when the user close to the high-voltage zone. However, it only detects voltage levels above 4kV, the operation is not convenient enough and the size is large. YJ-AM series of Chinese company is small in size, but only can detect selected voltage levels and cannot measure the electric field intensity. More importantly, many existing near-electrical warning devices need to pre-select the voltage level. It's not convenient enough and easy forgetting to adjust the level.

The current popular positioning technology include GPS, radio frequency identification, WIFI, ZigBee, UWB [1], Bluetooth, vision based, and so on [2]. Among them, compared with the other positioning technology, UWB has its advantage of high accuracy, low consumption, strong anti-interference ability [3,4]. At the present, the Localizers System of AETHER WIRE&LOCATION company is a relatively mature UWB positioning solution. The system uses well-known RTT (Round Trip Transmission) based TOA algorithm, where each base station makes RTT with a tag and find the final position of tag from TOA equations [5].

Based on the above analysis, there is currently no effective warning device on the market that integrates the positioning function and the near-electricity warning function. The paper proposes a warning device that use UWB technology to real-time positioning worker and simultaneously measure the electric field intensity. It is convenient to warn workers of the high intensity area of the electric field and to provide more detailed monitoring information for supervisors.

The rest of the paper is organized as follows: Section II provides an overview of existing technology include electric field intensity and location technology. Section III introduces our system design. It includes the electric field sensor, the locating algorithm, hardware and software. Section IV reports experiment results and Section V concludes the paper.

III. SYSTEM DESCRIPTION

A. Electric Field Sensing

The methods of measuring the electric field intensity include capacitor charging method, potential balancing method, charges sensing method. Compared with the other methods, the charges sensing method has high accuracy and the detected signal is approximately proportional to the electric field intensity. Therefore, the charges-sensing method is adopted in the paper.

The electric field sensors can be classified into electrical sensors and optical sensors. The electrical sensor has its advantage of the simple structure, producing simply and low cast, so is widely used in electric filed measurement. Its basic working principle can be expressed as: the surface of the metal plate in the electric field will accumulated induced charges which at the same frequency as the electric field. The stronger the electric field, the more the induced charges. By converting the induced charges to voltage or current signal and measuring it, we can indirectly know the electric field intensity.

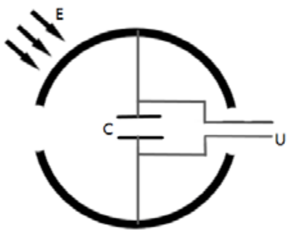

FIGURE I. SPHERICAL ELECTRIC FIELD SENSOR

A typical electrical sensor is the spherical sensor [6], as shown in Fig. 1. The induced voltage value U of the internal capacitor C can be modeled as Eq. 1.

$$U = \frac{-3\varepsilon\pi R^2 E}{C} \quad (1)$$

Where c means the value of the capacitor C which one is known parameter, E means the electric field intensity which we want to measuring, R means the radius of the spherical sensor which be measured, ε means the dielectric constant in air, π is circular constant, U means the induced voltage value of the internal capacitor C.

Therefore, we can know the electric field intensity by measuring the voltage value U.

B. Position Locating

In the location system, posited tags receive the signal of base stations(BS) which are known position and based on the orientation, energy or time difference of the arriving signal to calculate the position of the tag. UWB locating system is mainly composed of UWB tag, UWB base station and location engine, as shown in fig.2.

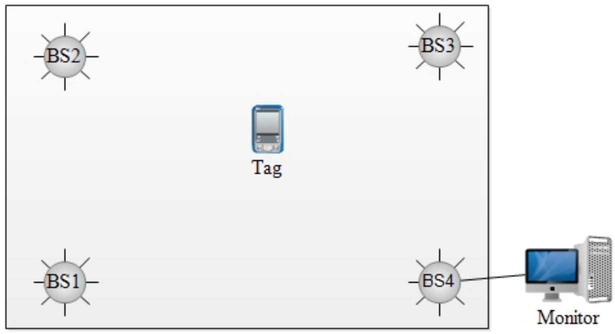

FIGURE II. POSITION LOCATION METHOD

Tag is surrounded by three BS and the tag and three BS lie on the same plane. Let (x, y) denote the location of the tag, (x_i, y_i) denote the location of BS i. Tags make RTT and communicate with All BS respectively. Tags has themselves processing unit which runs the position location procedure and calculates itself final position. All BS are connected to the service via wired or wireless link which shows the position of all tags on the map.

Based on the nano-level time resolution ability of the UWB technology, using two-way range(TWR) and time of arrival(TOA) Eq. 2, the centimeter-level positioning accuracy can theoretically be achieved. However, due to the interference of the multipath or the non-line-of-sight(NLOS) effect in the UWB signal propagation process, the positioning accuracy is degraded. In addition, the occasional disturbances will affect the stability of the positioning, especially in the case of people moving. Fortunately, the algorithm proposed in [7,8] can solve these problems well.

$$d_i = cT_i = \sqrt{(x_i - x)^2 + (y_i - y)^2}, i = 1, 2, 3, \ldots \quad (2)$$

Here, $d_i(i = 1,2,3, \ldots)$ are distance between the tag with BS i, c is the light speed, $T_i(i = 1,2,3, \ldots)$ are the fly time of UWB signal from tag to BS i.

C. Hardware Design

Although the induced voltage of the spherical sensor is proportional to the electric field intensity, the fabrication of the sensor is more complicated than the flat-panel sensor. In addition, the measurement results of the flat-panel sensor are close to the spherical sensor, and the theoretical error is less than 3% proved in [9]. Based on above analysis, the paper adopts the flat-plate sensor.

The UWB transceiver module is the key positioning devices of the paper. The DW1000 chip produced by DecaWave Company is the most advanced UWB signal processing chip on the market, which can realize high-precision positioning function. The chip transmits data through the serial peripheral interface(SPI) with the microcontroller unit(MCU), and calculates the RTT between the tag and the anchor. The chip contains a receiver, a transmitter and a SPI. This paper selects this chip as the UWB transceiver chip.

This paper selects the STM32F1 series of CortexM3 cores as MCU which is a 32-bit ARM microcontroller. The working frequency of the MCU can be up to 72M and computing speed is fast. It has a 12-bit ADC, and conversion frequency of up to 1Mhz. More importantly, it has SPI interface that can connect to the DW1000 chip.

The hardware block diagram of the paper is shown in Fig.3.

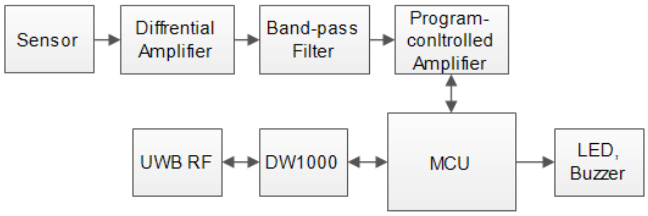

FIGURE III. HARDWARE BLOCK DIAGRAM

The electric field signal sensed by the sensor is a low frequency and very weak signal, and is easily susceptible to noise interference from various external factors. Therefore, a differential amplifying circuit(DFAC) is used at the front-end to suppress the interference signal from entering the back-end processing circuit, as shown in Fig.4. The DFAC uses an OPA2227 chip which has a strong ability to suppress the noise signal.

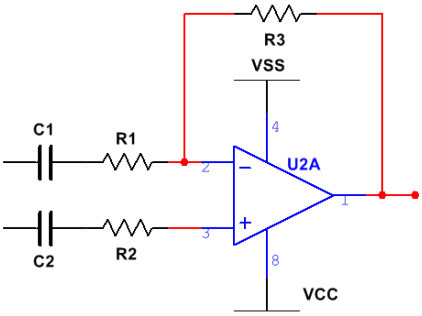

FIGURE IV. DIFFERENTIAL AMPLIFIER

Since this device mainly induces the power frequency electric field with a frequency of 50 Hz, it is necessary to extract the 50 Hz signal and filter out other irrelevant signals. The paper used an active second-order band-pass filter, which is a negative feedback filter, as shown in Fig. 5. And then the program-controlled amplifier circuit is designed to enable the circuit to detect a wide range of voltage levels (10~750kV). The circuit is used to adjust the voltage signal to a suitable range.

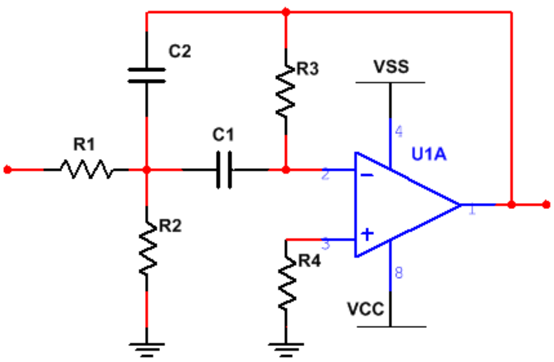

FIGURE V. 50 HZ BAND-PASS FILTER

The UWB positioning circuit is composed of a UWB antenna and a DW1000 chip, and is mainly responsible for transmitting and receiving UWB signals. MCU is an important device to realize the core function of the design. It mainly controls the DW1000 chip communication with other device, calculates the RTT and locates based on TOA algorithm, reads the output voltage value of the near-electrical warning module, and draws the dangerous area map according to the positioning and electric field intensity. When the electric field intensity is too large, gives an audible and visual warning.

D. *Software Design*

The program is embedded in the MCU. One of its tasks is to collect the electric filed sensing signal and calculate the intensity. If the intensity exceeds the specified safety limit, an audible and visual warning message is immediately given. The MCU also communicates with the DW1000 chip through SPI, controls and acquires the communication data with BS, calculates the RTT and then locates itself position coordinates based on TOA. If the position coordinates cross the safe area, an audible and visual warning message will be given immediately. In addition, the MCU also draws the hazardous area based on the position coordinates and the corresponding electric field intensity. At the same time, the results such as hazardous area map, itself position send to the monitoring platform. The main program flow is shown in Fig.6.

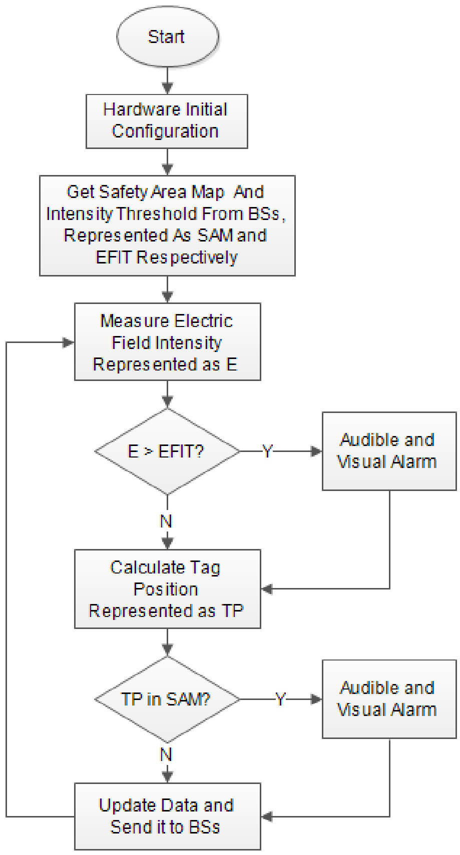

FIGURE VI. PROGRAM FLOW

IV. EXPERIMENT RESULTS

A. Intensity Measurement

The electric field intensity was measured under the 110kV power lines using the designed device and the RJ-5 power frequency electric field meter. In the experiment, we randomly selected ten position under the transmission line, and recorded the measured value respectively. The experimental results are shown in Table 1 below.

TABLE I. COMPARISON OF MEASUREMENT ACCURACY OF ELECTRIC FIELD INTENSITY

Measurement Position	Electric Field Intensity(V/m)		Relative Error
	The Designed Device	RJ5	
1	1504	1710	12.0%
2	1646	1786	7.8%
3	2143	2018	6.2%
4	2162	2330	7.2%
5	1917	2092	8.3%
6	2041	1841	10.9%
7	2083	1954	6.7%
8	1791	1826	1.9%
9	1812	1938	6.5%
10	2553	2261	12.9%

It can be seen from the Table 1 that the data measured by the designed device and the RJ-5 are not much different, and the error is within 13%. So the designed device can achieve well warning function based on the minimum risk criterion.

B. Positioning

Three base stations are arranged in a 10 x 10 m area. Then we set one standard walking line, which is named as L0. After that, we carried the designed device walking along with the line L0 and got samples of positioning each 10 microseconds. The sampled experimental data and actual data is shown in Fig.7. and the error result is shown in Fig.8.

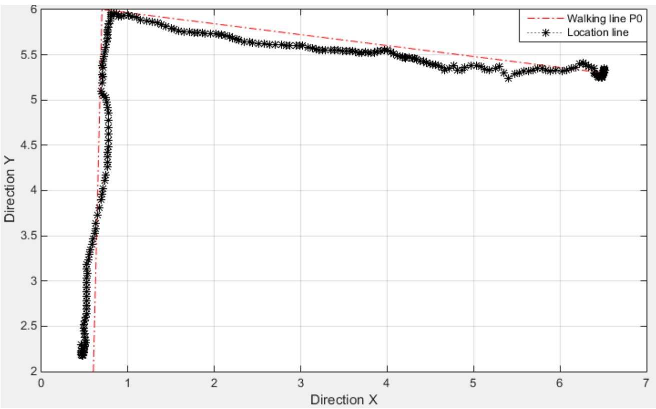

FIGURE VII. POSITION LOCATION EXPERIMENT RESULT

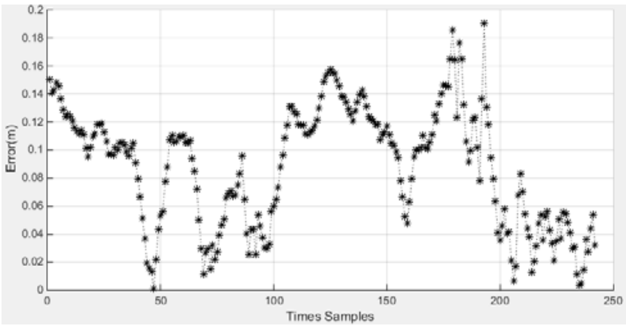

FIGURE VIII. POSITION LOCATION ACCURACY

From the experiment above, we can see that the positioning accuracy of the designed device is less than 19 cm, so the device meets the positioning requirements.

V. CONCLUSION

This paper describes a new type safety warning equipment, which has high warning accuracy, stable performance, small size, convenient operation and high positioning accuracy. It not only can effectively prevent workers from entering the high-voltage electrified area, touching charged equipment, but also can avoid the occurrence of dangerous accidents, and have good economic benefits. In order to promote the device to use, it will upgrade and improve its charging endurance, warning strategy, and add other function etc.

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REFERENCE

[1] S. Gezici, Z. Tian, G.B. Giannakis, Localization via ultra-wideband radio: a look at positioning aspects for future sensor networks, IEEE Signal Processing Magazine, 22(2005) 70-84.

[2] M. Al-Ammar, S. Alhadhrami, A. Al-Salman, A. Alarifi, Comparative Survey of Indoor Positioning Technologies, Techniques, and Algorithms, In Processing of the 2014 International Conference on Cyber Worlds(CW), Santander, Spain, 2014, pp. 1-8

[3] A.R.J Ruiz, F.S. Granja, Comparing Ubisense, BeSpoon, and DecaWave UWB Location System: Indoor Performance Analysis, IEEE Transactions on Instrumentation & Measurement, 66(2017) 1-12.

[4] A. Eryildirim, M.B. Guldogan, A Bernoulli Filter for Extended Target Tracking using Random Matrices in an UWB Sensor Network, J. IEEE Sensors Journal, 16(2016) 1-1.

[5] H. Kim, Double-sided two-way ranging algorithm to reduce ranging time, IEEE Communication Letters, 13(2009) 486-488.

[6] K. Feser, W. Pfaff, A Potential Free Spherical Sensor For the Measurement of Transient Electric Fields, IEEE Transaction on Power Delivery, 103(1984) 2904-2911.

[7] M. Misakian, P. Fulcomer, Measurement of no uniform power frequency electric fields, J. IEEE Transactions on Industrial Electronics, 18(1983): 657-661.

[8] K. A. Horvath, G. Ill, A. Milankovich, Calibration method of antenna delays for UWB-based localization systems, in 2017 IEEE 17th International Conference on Ubiquitous Wireless Broadband(ICUWB), Salamanca, 2017:1-5.

[9] Y. Guosai, Z. Linhui, A KFL-TOA UWB Indoor Positioning Method for Complex Environment, IEEE 2017 Conferences: 3010-3014.