# Design and Research of an Intelligent Insulation Rope Withstand Voltage Detection Device

Shaoqing Luo, Xuele Cui
18268887871@qq.com, 157720460@qq.com

EHV Branch Company of State Grid Zhejiang Electric Power Co., LTD

**Abstract**—With the gradual development of China's power grid system, in the process of carrying out the work of the power detection system, if the operator carries out the operation without protection, it will not only fail to ensure the quality of the operation, but also produce safety risks, which may even cause casualties. Based on the above considerations, the withstand voltage test of the insulating rope for live working is carried out to detect the insulation strength of the insulating rope, which can not only greatly improve the safety of the shop, but also improve the production efficiency of electric power work, thus providing a solid security guarantee for China's electric power transportation and industrial production. This paper mainly studies the design and research of the withstand voltage test device of the insulating rope for live working.

**Keywords**-Withstand voltage test; Insulating rope; On-line Detection;

## 1 INTRODUCTION

With the development of urbanization in China, the area of the power grid is getting larger and larger, the load of the power grid is also getting larger and larger, and the environment where the power grid is located is also diverse, so sometimes the branch will cause power grid failures. The insulating rope for live working is frequently used in the live working of power transmission and distribution, which is an important tool to ensure the safety of live working. In order to ensure the safety of the insulating rope during the operation, the insulating rope needs to be completely tested for insulation resistance before each use, to prevent the safety accident caused by the insulation effect failure of the insulating rope.

At present, before electrification, the operator usually uses a manually held insulation resistance detector to pull the insulation rope to contact the two electrode pieces on the resistance detector uninterruptedly, so as to realize the voltage loading on the insulation rope at a certain length. Whether the insulation effect of the insulation rope is qualified is judged by detecting the resistance value of the insulation rope of the measured length. When using, the operator pulls the middle position of the insulation rope, The insulating rope is carried and used for climbing in the form of bending at the middle position. In this way, both the detection process and the use process can only be achieved by pulling the insulating rope out of the winding device. Moreover, the centering operation of the insulating rope is more troublesome, which not only takes more time, but also has lower work efficiency. Moreover, the insulating rope is easy to knot and is not easy to be re collected, Due to the complexity of outdoor working environment of power transmission and distribution lines, the proficiency of operators and the sensitivity of pressurizing devices, the

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detection and use of insulating ropes greatly limit the efficiency of live working and affect the safety of live working.

Therefore, there is an urgent need for a technical solution to solve the technical problems of the existing live working insulation rope detection and use process, which takes a lot of time, greatly limits the efficiency of live working, and affects the safety of live working.

## 2 VOLTAGE WITHSTAND DETECTION PRINCIPLE AND COMPONENTS OF LIVE INSULATING ROPE

The testing instrument adopts advanced equipment manufacturing technology, high-end CNC processing technology and CNC equipment, and key imported component system according to its own system characteristics to ensure the effective application of precision servo system. The mechanical part includes the test frame and winding device. A sufficient number of stainless steel pipes are set on the test rack, and the surface is covered with high-strength insulating cotton to ensure the insulation performance of the system. The multi-point grounding technology is used to ensure the safety of the system and improve the operating efficiency. The test frame consists of a main shaft, a support rod, a test mechanical arm, etc., wherein the main shaft can stretch out through the epoxy resin plate arranged in parallel to fix the device. The connecting piece connects the body at both ends, and then comes out of the U-shaped device. The body is bolted to the fixed test frame to ensure the insulation and stability of the test system.

Secondly, the core technology of the device also uses a winding device, which is composed of a base plate, a support frame, a bearing and insulating materials. By adjusting the controllable distance of the device itself, it can effectively determine whether the withstand voltage distance of the insulating rope is stable. During the actual test and use, the device can rotate 360 degrees to maximize the contact area. When connecting the high-voltage end of the device, the insulating material can effectively block the discharge effect of other metal materials, so as to achieve the purpose of safe production.

## 3 HARDWARE PART OF LIVE INSULATING ROPE TEST SYSTEM

The detection system adopts modular design structure, mainly consisting of embedded system control unit, high-voltage drive unit, insulation performance detection unit, historical data storage unit, data printing unit, rope length calculation unit of winding system, temperature and humidity detection unit, wind speed detection unit, key processing unit, LCD screen display unit and power supply unit. The structural unit is shown in the figure below:

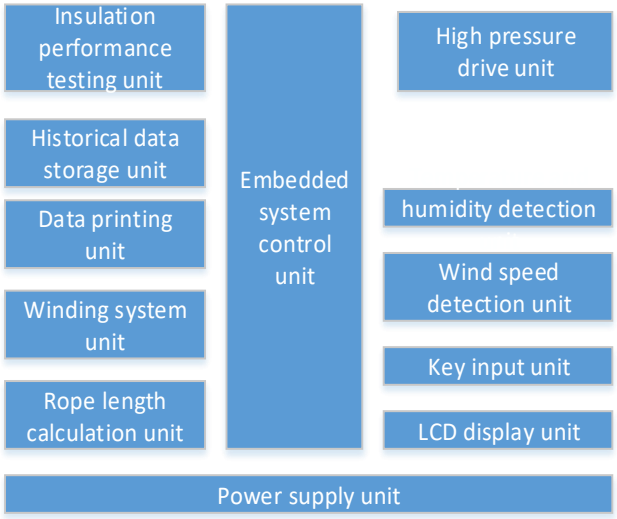


**Fig 1.** Structural unit

### 3.1 Embedded system control unit

The system control unit adopts stm32 single-chip microcomputer. STM32 series microcontroller is a 32-bit microcontroller based on ARMCortex-M as the core introduced by ST (Italian Semiconductor), which supports a wide range of 32-bit applications. Literature [1] uses STM32F1 series chips to design a high-precision solar tracking system based on optical fiber array; Literature [4] completed the design of X-type quad rotor UAV based on STM32F4 series chips. STM32F4 series chips are high-performance microcontrollers based on ARM Cortex ™ M4 core with ultra-low power consumption. The STM32F407 of this series has a working frequency of 168 MHz, 140 fast I/O ports and up to 15 standard communication interfaces, 2 CAN interfaces, 4 USART, 2 UART, 3 I2C interfaces, 3 SPIs, and 1 SDIO interface. It can work under low voltage (1.8~3.6 V). Based on these resources and characteristics of STM32F407, the requirements for power consumption, high performance and rich interfaces of the system measurement can be met. In addition, the normal operating temperature range of the chip is -40~+85 ℃, meeting outdoor working conditions. Therefore, this paper selects STM32F407 as the main chip and adds the peripheral circuit to realize the design of the live insulated rope test system.

### 3.2 Peripheral circuit design

#### 3.2.1 Power supply circuit

In order to simplify the power supply circuit, when selecting components such as sensors and actuators, components with power supply voltages in the same range should be selected as much as possible. Therefore, the entire attitude control system only needs two power supply standards: 5V and 3.3V. The external bus supply voltage is 7.4 V, so it needs to be realized by voltage conversion chip. In this paper, ADP3303 and LMZ12001 are used to realize 5V and 3.3V power

supply respectively. In order to stabilize the input and output without interference from other signals, a capacitor is connected in series between the input and output pins and the ground.

### 3.2.2 LCD display circuit

This scheme uses a 3.5 inch TFT LCD module, with a working voltage of 3.3 V and a maximum working current of 70 mA. It supports 320 × 240 resolution, built-in 230K memory display up to 256K colors, text and graphics can be displayed, LED backlight design is adopted, backlight brightness can be adjusted by using software, built-in simplified Chinese character library, support 2D BTE engine, and build a geometry acceleration engine at the same time, which can perform complex operations on display objects, such as image rotation function, scroll function, graphic pattern, double-layer mixed display and text amplification. These functions will save users' development time in TFT screen applications, improve the execution efficiency of MCU software, make the screen more colorful, display functions more abundant, and greatly enhance the display capacity of the screen. 8-bit or 16 bit bus interface is provided to facilitate connection with MCU. It has strong adaptability and flexible connection design.

### 3.2.3 Key input circuit

Because the GPIO of STM32 single-chip microcomputer is equipped with pull-up and pull-down inputs, the hardware part directly uses a key switch, with one end connected to GPIO and the other end connected to VCC. Through low-level interruption, it can determine which key the user pressed.

The switch used for button shaking elimination is usually a mechanical elastic switch. When the mechanical contact is opened or closed, due to the elastic effect of the mechanical contact, a key switch will not be connected stably when it is closed, and will not be disconnected at once when it is disconnected. Therefore, there is a series of jitters at the moment of closing and opening. To avoid this phenomenon, the key is used to eliminate jitters.

The jitter of keys is imperceptible to humans, but it is completely perceptible to the microcontroller, and it is also a very "long" process, because the processing speed of the microcontroller is at the "microsecond" level, and the jitter time of keys is at least at the "millisecond" level.

The level waveform of one key action is shown in the figure below. There is jitter, and the jitter time of the front and rear edges is generally between 5ms and 10ms. Due to the very fast running speed of the microcontroller, it will be detected that the low-level judgment key is pressed when the A moment passes. When it comes to time B, the microcontroller will also detect a high level, mistakenly thinking that the key is released, and then it detects a low level at time C, judging that the key is pressed. Over and over again, there may be many press actions within 5-10ms, and each press action is judged differently.

### 3.2.4 Wind speed detection circuit

STM32f407 single chip microcomputer monitors the analog signal of the wind speed and direction module in real time, converts the analog signal into digital quantity through AD conversion, calculates the wind speed and direction through calculation, and then displays them on the LCD screen, with the display accuracy of 0.1m/s and the range of 0-30m/s. The wind direction angle is in degrees, and the range is 0-360 degrees.

For mechanical wind speed and direction sensors, arrow type wind direction sensor and three cup type wind speed sensor are the most common. For example, three cup type wind speed sensor is composed of three or four conical or hemispherical empty cups to form its sensing part. During installation, the shell of the hollow cup needs to be fixed on a tripod star shaped bracket or a cross shaped bracket. The arrangement direction of the hollow cup concave is the same, and the cross arm needs to be fixed on a vertical rotation axis. The application of wind speed and direction sensors can make people better use of wind energy, which is conducive to the development of new energy wind power generation technology.

The working principle of the ultrasonic wind speed and direction sensor is to measure the wind speed and direction using the ultrasonic time difference method. Because the propagation speed of sound in the air will be superimposed with the air speed in the wind direction. When the propagation direction of ultrasonic wave is the same as the wind direction, the speed of equipment will be faster, and when the propagation direction of ultrasonic wave is opposite to the wind direction, the speed of equipment will be slower. Therefore, under the same detection conditions, accurate wind speed and direction can be obtained through calculation.

A typical example of measuring wind speed using the calorimetric principle is the anemometer. Its measuring principle is to put a thin metal wire into the fluid, and then heat the wire with electric current to make the temperature of the wire higher than that of the fluid. Therefore, the wire anemometer is called "hot wire". When the fluid flows through the wire in the vertical direction, it will take away part of the heat of the wire and reduce the temperature of the wire. Anemometer is an instrument that can measure low wind speed. It consists of a hot bulb probe and a measuring instrument. The cold end of the thermocouple is connected to the phosphor copper column and directly exposed to the air flow. When there is current passing through the heating ring, the temperature of the glass ball will increase. The increase is related to the wind speed, and the increase is large when the wind speed is small; On the contrary, the growth rate is very small. The rise amplitude is indicated on the instrument by the thermocouple. Check the correction curve and find out the current wind speed according to the readings of the instrument.

### 3.2.5 Temperature and humidity detection circuit

The temperature and humidity sensor adopts chip DHT11 with I2C interface. It is a dual-use sensor with calibrated digital signal transmission. It has special digital module acquisition technology and temperature and humidity sensing technology. It has high reliability, long-term stability, low cost, temperature measurement and humidity measurement, fast response, strong anti-interference ability, and long signal transmission distance. It can be connected to the I2C interface of stm32,

### 3.2.6 High voltage drive circuit

The high-voltage generator part adopts the stm32 DDS principle to control the internal DA to simulate various signals, isolate and boost the voltage through the transformer, and then use the voltage doubling circuit to change AC to high-voltage DC. Then, the 12V DC voltage is increased to 3000V DC voltage through resistance capacitance filtering.

### 3.2.7 Insulation performance detection circuit

The high-voltage detection manipulator is clamped on both ends of the insulating rope respectively, and then STM32F407 controls the boost circuit. After the voltage rises to the setting value, the resistance of the insulating rope is measured. The resistance result of the insulating rope can be calculated through differential calculation, and then displayed on the LCD display for storage and printing.

### 3.2.8 Historical data storage circuit

The storage circuit adopts W25Q64 (64M bit). W25Q16 (16M bit) and W25Q32 (32M bit) are serial Flash memories that provide a memory solution with the minimum space, pin and power consumption for the system. The 25Q series is more flexible and superior in performance than ordinary serial Flash memory. Based on double/quadruple SPI, they can provide data to RAM immediately, including storing sound, text and data. The chip supports a working voltage of 2.7V to 3.6V. The current is less than 5mA under normal operation and less than 1uA under power failure. All chips are provided with standard packaging.

### 3.2.9 Data printing circuit

The printing module is EM5820, which is an embedded thermal printing module developed by Guangzhou Youku Electronics Co., Ltd. The EM5820 can support thermal printing, and the maximum printing width is 58mm. The products are mainly used in medical equipment and electronic weighing equipment, and can also be used in other occasions where receipts need to be printed. The EM5820 connects the equipment through USB/TTL/RS232 interface.

## 4 PROCESSING PROCESS OF INSULATION STRENGTH DETECTION SOFTWARE OF LIVE INSULATING ROPE

During the development of insulation rope strength detection with stm32f407ret6, the software development is implemented using KEIL5. After the system is powered on, STM32f407ret6 enters the main function, loads various peripheral drivers, and then performs self inspection. If the self inspection is normal, the LCD displays the system information. After the user inputs the test button, the system enters the detection subprogram, rolls the rope winding device, calculates the length of the insulation rope, and loads the high voltage after reaching the user set length, Measure the insulation rope resistance. After the measurement is completed, stop the high voltage, detect the ambient temperature and humidity, wind speed and direction, and then conduct the system calculation. After the calculation is completed, the results will be displayed on the LCD screen. If the insulation requirements are met, the next test will be carried out automatically. If the alarm is generated, the alarm signal will be given. Wait for the user's key input.

## 5 FIELD TEST RESULTS AND ANALYSIS

The instrument can measure the insulation strength of insulating rope by itself, which solves the problem of manual detection. The operation difficulty is reduced and the production efficiency

is improved. The operation experience and research results show that the system brings a lot of convenience to field testing. It fully meets the on-site needs.

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