An Electricity Inspection System of UHV Transmission Lines based on Beidou Satellite Communication

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Abstract. With the construction and development of UHV power transmission projects in China, safety are becoming increasingly important in the line operation and maintenance. The line operators must verify the electricity status of the transmission line before they carry out the work of maintenance. Due to the characteristics of UHV line, the electricity detection device on UHV line is different from the traditional ones. In this paper, an electricity inspection system based on Beidou satellite communication technology is established by means of non-contact Micro-Electro-Mechanism System (MEMS) electric field sensor. The system includes electricity detection device, handheld inquiry device and monitoring center. Experiments at actual transmission line verified the validation of the electricity inspection system.

1. Introduction

Energy resources are distributed unbalanced in China. The central and eastern regions which have large population and relatively developed economy consume large amounts of energy, but lack of energy resources. Most of the coal, water and wind energy resources are distributed in the western and Northern regions. UHV transmission has the characteristics of large transmission capacity, long transmission distance, small line loss and less land occupation, having the ability to transfer abundant energy resources from the western and northern regions to the central and eastern regions on a large scale [1]. It plays an important role in guaranteeing power supply, promoting clean energy development, improving the environment and improving the security level of power grid [2, 3].

With the construction and development of UHV power transmission projects in China, safety are becoming increasingly important in the operation and maintenance of UHV transmission lines. When a line encounters a fault or line maintenances in condition of power off are needed, line operators should verify the live status of the working line before working [4]. It must guarantee that the equipment to be operated is in power-off state, then the maintenance and emergency repair work can be carried out. It is necessary to avoid the occurrence of malignant accidents that damage equipment and endanger personal safety. Therefore, it is of great significance to use electricity detection devices on transmission lines to provide security for operators.

At present, the operators operated and maintained transmission lines mainly verify the live state of the operation lines by means of electricity detecting devices, which can be divided into two types,
contact and non-contact. The contact electricity detecting device is composed of metal probe (hook), signal processing unit and insulated operating pole. Operators are required to operate insulated operating poles during electricity inspection [5, 6]. However, UHV transmission lines have high tower height, large tower head size and long insulator strings. When contact electricity detecting device is used to UHV transmission line, it will greatly increase the labor intensity of the operators because the insulated operating pole is required to have a long length due to the large relative ground distance of UHV lines. Moreover, the longer the insulated operating pole is, the easier it is to deflect and the less easy it is to operate [7]. Non-contact electricity detecting device mainly uses high voltage electric field sensor, ultraviolet sensor, and ultra-high frequency partial discharge sensor to measure the signal around the line to determine whether the line is live. The high voltage electric field method is affected by the ground environment, tower structure, wire layout and other factors, and its ability of anti-interference is poor, and it has some defects such as false alarm and blind area of detection [8]. Ultraviolet and ultra-high frequency partial discharge method is greatly affected by weather conditions and equipment operation conditions, and the measurement accuracy is poor [9, 10]. Non-contact electricity detecting device does not need direct contact with transmission lines, so it has a very important application value to ensure the safety of the operators.

In this paper, an electricity inspection system based on Beidou satellite communication technology is established by means of non-contact Micro-Electro-Mechanism System (MEMS) electric field sensor. The system includes electricity detection device, handheld inquiry device and monitoring center. The electricity detection device is installed on the transmission line. The operator can inquire the electricity state of the line in real time by using the handheld device. All of the electricity state of the lines in monitoring area are stored and displayed on the monitoring center. It can greatly reduce the work intensity of the operators. In addition, the accuracy of electricity detection can be improved by multi-point detection of the same line. The positioning function of electricity detection device and handheld device can also effectively prevent operators from climbing the wrong tower and improve the safety of operation.

2. Design of Electricity inspection System

The transmission line covers a wide range of areas. After collecting the electricity information, electricity detection devices need to transmit it to the monitoring center through effective data transmission. Beidou Satellite Navigation System’s unique short message communication mode can carry out two-way short message communication in the coverage area of the system. The use of Beidou short message communication can improve the reliability of UHV transmission line electricity inspection System.

2.1. Electricity Detection Device of UHV

The electricity detection device collects the electric field or magnetic field signals of UHV transmission line, communicates the information between electricity detection sensor and Beidou short message communication module inside the device and the information between Beidou short message communication module of electricity detection device and monitoring center or handheld inquiry device.

The hardware design is shown as fig.1.

Non-contact sensor of MEMS is adopted. By measuring the electric field near the line, it realizes non-contact identification and alarm of bipolar operation, unipolar operation and bipolar outage of UHV transmission line. It has the characteristics of low power consumption, convenient operation, high recognition accuracy and high efficiency and intelligence.

The power supply system is mainly composed of photovoltaic panels, solar controllers and solar colloidal storage batteries. By choosing appropriate power modules, the power supply system is constructed. By choosing appropriate detection sensor, CPU core module and Beidou communication module, the device can realize the function of line electricity detection and tower location, and complete remote connection.
2.2. Handheld Inquiry Device

An embedded handheld terminal for inquiring and displaying electricity status of transmission lines is developed, which collects, stores and communicates electricity information and supplements thematic map information of transmission lines. The handheld inquiry device has the following functions:

1) Real-time acquisition, processing and communication of line position information and electricity status.

2) Transmission line map and line database.

3) It can use general embedded handheld device OS and common software system, and can easily upgrade.

In order to achieve the above functions, the device uses four modules: network communication module, data query module, message display module and data processing module. The software design diagram of handheld inquiry device is shown as fig.2.

The device provides two kinds of network communication modules: Beidou network communication and mobile network/WiFi communication. Beidou network communication mainly establishes communication link inquiry function of tower node, server terminal and handheld terminal. Beidou network communication mainly solves the network communication problems of the near-end query function in remote areas and areas with poor mobile network signals. Mobile network communication mainly solves the communication problems of remote query function and database update function.

The data query module can be divided into Beidou query mode and mobile network query mode. In Beidou query mode, users mainly rely on their own geographic location information to query, which is suitable for short-range query. Mobile network query mode is mainly suitable for remote query through the key word of tower number.

In order to intuitively express data content, Baidu Map is introduced, and the received information is labeled on Baidu Map in real time.

When the message is received, it needs to be processed. The method of processing is to store it in the database of the handheld terminal and screen the basic invariable information such as tower lines from the database of the handheld terminal to display on the interface. The purpose of this is to reduce the communication burden of Beidou short message and reduce the amount of information transmitted as much as possible.
2.3. Monitoring Center
Monitoring center interacts with electricity detection device and handheld inquiry device, providing basic map services, line equipment management, line electricity state monitoring data acquisition and display, historical information query and analysis functions. The software design of monitoring center is shown as fig.3.
3. Experiment and Discussion
In order to examine the validation of the electricity inspection system, some experiments were performed at actual transmission line. The experiments were carried out on different towers of 1000kV UHVAC transmission line, as shown in Table 1.

| Number | Transmission line | Tower No. | Tower Type |
|--------|------------------|-----------|------------|
| 1      | Jindongnan-Nanyang-Jingmen 1000kV UHVAC | 551#      | Straight tower |
| 2      | Jindongnan-Nanyang-Jingmen 1000kV UHVAC | 552#      | Strain tower |

On the day of the experiment carried on 551# tower and 552# tower, the temperature was 26-30°C, the humidity was 60%-70%, and the wind speed was 3-5m/s. In order to select the optimal installation site on the tower, four typical sites on the tower were selected to detect the electricity state of the line using electricity detection device. The detection sites on the tower are shown as fig.4.

The electric field values at 8 sites were measured. The average electric field values on the conditions of live line and power off are shown as table 2.

| Tower No. | Test site No. | Test site location | Electric field value of live line (kV/m) | Electric field value of power off (kV/m) |
|-----------|---------------|--------------------|-----------------------------------------|----------------------------------------|
| 551#      | site1         | on the tower body and its height is equal to lower side phase conductor | 12.82                                   | 0.06                                   |
| 551#      | site2         | on the cross arm directly above the lower side phase conductor | 12.81                                   | 0.06                                   |
| 551#      | site3         | on the tower body and its height is equal to upper middle phase conductor | 12.98                                   | 0.07                                   |
| 551#      | site4         | on the cross arm directly above the upper middle phase conductor | 12.81                                   | 0.07                                   |
| 552#      | site5         | on the tower body and its height is equal to lower side phase conductor | 15.63                                   | 0.06                                   |
| 552#      | site6         | on the cross arm directly above the lower side phase conductor | 16.52                                   | 0.06                                   |
| 552#      | site7         | on the tower body and its height is equal to upper middle phase conductor | 22.64                                   | 0.08                                   |
| 552#      | site8         | on the cross arm directly above the upper middle phase conductor | 12.05                                   | 0.08                                   |
As shown in table 1, we can see that the measured electric field value is less than 0.1 kV/m when the 1000 kV single circuit line is power off and is more than 12 kV/m when the line is live. Therefore, the alarm threshold can be set to determine whether the line is live or not. In addition, the field experiment also verified the effectiveness of communication of the designed electricity inspection system.

4. Conclusion
In this paper, an electricity inspection system based on Beidou satellite communication technology is established by means of non-contact Micro-Electro-Mechanism System (MEMS) electric field sensor. On-line monitoring is adopted in the system and it is convenient for the operators to inquire the electricity state of transmission line. It can greatly reduce the work intensity of the operators. In addition, the positioning function of electricity detection device and handheld device can also effectively prevent operators from climbing the wrong tower and improve the safety of operation.

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