Online monitoring and early warning technology for the status of earth wire for overhead line

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Abstract: Overhead lines for wind power transmission in the southern region have the characteristics of large tower-line elevation, across thick ice areas, harsh natural environments, and difficult maintenance. Unpredictable line breakage accidents often occur, affecting the stability of the social power supply. This paper designs and introduces a technology based on intelligent perception technique for online monitoring of the earth wire, which can realize long-term real-time online monitoring of the state of the earth wire of overhead lines and solve the problem of line monitoring from wind power transmission and fault inspection and troubleshooting. Now the test and monitoring work of an overhead transmission line has been completed during the ice period, and the test results show that the technology has good monitoring performance.

1. Introduction
Wind power transmission overhead lines are often interrupted due to lines covered with ice in winter, sudden strong winds, strong local convection and natural factors such as landslides and mudslides, resulting in interruptions to the social power supply. If not detected and dealt with promptly, affecting the operation of the entire line, resulting in incalculable consequences [1]. Due to the extremely harsh natural environment in some areas of the south, and the high-altitude, high-voltage transmission operating environment of the overhead lines with wind power transmission, operators on the conventional line maintenance site are hazardous [2,3]. Therefore, in the daily operation of wind power transmission lines, it is necessary to adopt a scientific and effective maintenance mechanism to maintain the stability of the social power supply.

To minimize the impact of line disruptions on the power grid, improve the safety of maintenance personnel and reduce the difficulty of maintenance, this proposal is based on extensive research into existing transmission line disconnection prevention and maintenance technologies at home and abroad, combined with the strategic objectives of the State Grid Corporation in the new era to build a world-class energy internet enterprise. This plan is to propose the intelligent perception and disconnection early warning online monitoring technology for Hunan regional transmission lines based on ubiquitous Internet of Things (IoT) and intelligent perception technique, etc. The application
of this technology will greatly improve the automation level of overhead transmission lines in China. Conventional broken-line diagnosis and maintenance require personnel's on-site investigation, while online intelligent perception monitoring technology for lines will transmit the on-site situation and related technical indicators of the disconnection risk areas obtained by the sensor to the technology center in real-time through the IoT technology, which can reduce broken-line risks by monitoring the region with timely intervention. At the same time, compared with traditional maintenance technology, it has low-cost both on economic and labor, a high broken-line detection rate and can determine the fault occurrence area to a specific section of the line, providing a better auxiliary role for the development of maintenance work. Meanwhile, the application of this technology can strongly promote the intelligent management of the power system. A large number of monitoring data will provide big data for the management of the power grid. With big data analysis, it can effectively integrate communication and power infrastructure resources, improve the utilization of China's existing power system infrastructure, so that China's power facilities system to achieve rapid, efficient and sustainable development.

2. Cloud Technology of Power Internet of Things (IoT)

2.1. Principle of intelligent perception and IoT for power facilities
The IoT architecture of power facilities based on intelligent perception technology consists of a perception layer, a transport layer and an application layer.

The perception layer forms a large, connectable network of all power facilities through the installation of various devices such as smart sensors, 2D codes, infrared sensors and laser scanners on various types of power equipment. A unified perception information model is established in this network environment, which in turn brings together data from the power grid equipment to the controller and finally stores the data in the power intranet through the gateway.

The main task of the transport layer is to ensure the safe and reliable transmission of information to the application layer. In this regard, a high-performance "terminal access communication network" can be established, and a "unified communication protocol" can be developed for the transport layer, which is compatible with various transmission modes and improves the security and reliability of transmission.

The application layer, as the core of the intelligent perception IoT framework structure, monitors equipment status, faults and working environment through the processing of data transmitted at the network layer, and can improve its own data model, structure and service components through the application layer management platform to store and deploy information on facilities and equipment to achieve deeper resource sharing and functional applications.

2.2. Principles of big data and cloud computing technology
Big data technology is the application of advanced intelligent algorithms such as frequent pattern mining, cluster analysis and Bayesian networks to extract valuable information from massive data sources [4]. Online real-time monitoring will generate massive amounts of data that cannot be quickly captured, processed and managed by conventional numerical software. Relying on big data technologies transforms massive amounts of monitoring information into information assets that are useful for improving decision-making, insight discovery and process optimization. Clearly, big data analysis must be underpinned by a powerful computer, which takes up a lot of computer resources. Cloud computing technology enables ordinary computers and even mobile phones to access cloud-based server data centers, call on their computing resources and perform calculations according to user needs, enabling big data analysis.

3. Technical solutions of online monitoring systems for overhead transmission lines
The power facility IoT perception layer senses and captures its status information with the devices such as radio frequency identification, QR codes and sensors. Subsequently, the signal transmitter of
intelligent sensing equipment, will transmit the captured perception information through the reliable network protocols at the network layer to the management platform of center equipment facilities in the power intranet. Each application layer of the platform identifies and processes the received intelligent information, and finally realizes the status monitoring, status warning and remote emergency processing of fault conditions of power facility equipment. Based on this, this paper designs an integrated technology featuring a new sensor, data processing and signal analysis, low-power transmission and network communication, etc., realizing all-weather real-time monitoring of transmission line status. The back-office management center stores and intelligently analyses the collected information, forming intuitive images and diagrams for easy transmission, early warning, diagnosis and emergency technical handling of power line faults.

3.1 System architecture and functional implementation

The online monitoring system mainly consists of a front-end monitoring system (perception layer), a network transmission system (transmission layer) and a back-end monitoring master station (application layer). The front-end monitoring system mainly includes the integrated main chassis, power supply unit, ultrasonic six-element sensor, tension/inclination sensor, HD camera (HD dome) and other parts. The network transmission system is composed of GPRS+3G/4G dual-channel communication or WiFi+fiber optic communication. The back-end monitoring master station system is composed of a director center and multiple sub-monitoring centers. The system structure diagram is as follows:

![Figure 1 Schematic diagram of the structure of the online monitoring system](image)

3.1.1 Tension and inclination sensors

The tensile force sensor has a measuring range of 7-55 T and can be configured according to the force stressed on actual lines; the actual sensor is shown in Figure 4.3. The shell of the sensor is made of stainless steel. It can withstand a working temperature of -40°C~+85°C, and can meet the highly harsh natural environment. The specific technical parameters are shown in Table 4.2. With the inclination sensor measuring dual-range axis ≥ ± 60°; measuring accuracy: ≤ ± 0.1°; measuring resolution: ±0.01°.
3.1.2. **Ultrasonic six-element meteorological sensor**

Figure 3 shows the structure of the meteorological sensor. The sensor can collect real-time information on the service environments of six transmission lines, including temperature, humidity, wind speed, wind direction, air pressure and rainfall.

3.1.3. **Power supply support system**

Depending on the service environment of the monitoring device, three intelligent perception power supply solutions are proposed:

1. accumulator + solar energy;
2. accumulator + solar energy + earth wire to take electricity;
3. accumulator + solar energy + wind energy;

According to the actual use of the site, the above three options are combined in a modular and reasonable way. The accumulator can independently and continuously maintain the monitoring equipment for 30 days in the case of ice loaded on lines. Solar energy can meet the need for a long and reliable power supply for equipment in the field. The monitoring system is combined with intelligent power management technology. On the main control CPU board of the system, the battery voltage and current real-time monitoring module is integrated, and through the monitoring and sensing of the battery voltage, the remaining power can be captured and the usage of the battery can be monitored in time.

4. **Online monitoring test of the earth wire for overhead transmission line**

4.1. **Online monitoring system installation**

4.1.1. **Monitoring sub-host installation**

While installation, we must find an angle steel with a horizontal distance of about 15 meters from the side phase insulator string on the cross-arm, hang the chassis clamps to the edge of the angle steel, clamp the safety band on the angle steel, and tighten the screws with a wrench. After all the sensor wires are connected, load the rain cover and tighten the screws on the clamps to ensure that the extension is fixed reliably; ensure that the screws are in close contact with the tower and that the extension is grounded reliably. As shown in Figure 4.
4.1.2. **Sensor and camera installation**
Open the sensor mounting accessories, install the corresponding sensor in its monitoring position and tighten the connection screws to ensure that it works stably. Install the camera at approximately the same height as the monitoring extension. At a distance of about 3m from the monitoring extension on the tower cross-arms using angle steel to fit in, tighten the screws and adjust the monitoring field of view.

4.1.3. **Installation of the power supply system**
The power supply consists of the accumulator and solar cells to provide energy support for the extension. The accumulator is installed at a distance of about 3m from the right side of the monitoring extension on the cross-arms of the tower. Then use angle steel and tighten the screws to fix the bottom bracket to the tower, then adjust the solar cell panel. After the panel is facing the south, tighten the remaining screws to connect the bracket tightly to ensure that the extension works normally.

![Sensor installation](image)

(a) Tension and inclination sensor installation  (b) Six-element meteorological sensor installation

![Camera installation](image)

(c) Camera installation

**Fig. 5 Sensor installation**

5. **Conclusion**
The design and introduction of a technology based on intelligent perception technique for online monitoring of the earth wire were described in this paper. With all the technical measured taken to put into this study, the problem of long-term real-time online monitoring of the state of the earth wire of overhead lines will surely be conquered.

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