Multi-Sensor Network Cable Tunnel Monitoring System Based on GIS

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Abstract. In this paper, the main factors affect the normal operation of power cables and cable tunnel are introduced. In view of these factors, a multi-sensor network cable tunnel monitoring system based on GIS. In the system, cable temperature monitoring system, tunnel environment monitoring system, tunnel security system and tunnel video monitoring system are embedded in the GIS platform, and the high voltage cable, cable tunnel environment and auxiliary facilities are monitored and controlled, which is of great significance to ensure the stable and safe operation of the cable.

1. Introduction

With the development of power system, power cable has gradually become the main component of urban power network due to its advantages of safety, reliability, concealment, durability and little influence from external environment. Cable tunnels are the main measures to ensure safe and efficient operation of power cables and reliable power supply in cities. It is of great significance to effectively monitor and control the power cables in real time [1]. At present, the cable tunnel monitoring system is basically still in the primary stage. The devices in cable tunnels independently perform their specific and single monitoring functions. The information between devices cannot be shared efficiently and the connection between devices is poor, which leads to the difficulty of coordination and cooperation between devices. It is not a truly comprehensive cable tunnel monitoring system [2].

As the scale of urban power cables becomes larger and more complex, the current simple system cannot meet the maintenance requirements of power cables. In order to solve the problem, a multi-sensor network cable tunnel monitoring system based on GIS is proposed. In the system, a cable temperature monitoring system, a tunnel environment monitoring system, a tunnel security system and a tunnel video monitoring system are integrated and embedded on GIS system platform by using the field bus and embedded industrial Ethernet [3]. The system realizes the sharing of cable tunnel information, high intelligence and linkage of tunnel equipment, can intuitively and visually manage cable tunnels, and greatly improves the operation and maintenance level of power cables.
2. System Overall Construction

2.1. The Construction of Cable Tunnel Monitoring System Based on GIS

The cable tunnel monitoring system based on GIS adopts a hierarchical distributed hybrid network structure and consists of three layers. The first layer is a field measurement and control layer composed of sensors, auxiliary equipment and field servers. The second layer is a management and control layer composed of data processing and communication servers and other network devices. The third layer is remote control center based on GIS system. The function of the field measurement and control layer is to collect and upload the actual operation status information of power cables and equipment in tunnels. The function of management and control layer is to synthetically process the information collected by field measurement and control layer, and finally upload it to remote control center and issue control instructions to field measurement and control layer to realize intelligent management of cable tunnel. The function of remote control center based on GIS system is to collect, store and process the information data of cable tunnel, realize the information inquiry, control and GIS positioning of cable tunnel equipment. It can output various forms of data, reports, and charts and so on according to the specific requirements of users, so as to realize the intuitive and efficient management of power cable and tunnel facilities. Field bus technology is used in the field measurement and control layer, and embedded Ethernet technology is used in the upper management and control layer. Fieldbus technology in the field of industrial control originates from microcomputer network technology. It adds a user-oriented layer 8 to the OSI seven-layer model, and consists of physical layer, data link layer, application layer and user layer [4]. Embedded Ethernet is an embedded operating system based on microprocessor's software and hardware environment and embedded network protocols such as TCP/IP protocol [5].

![Block diagram of multi-sensor network cable tunnel monitoring system based on GIS](image)

**Figure 1.** Block diagram of multi-sensor network cable tunnel monitoring system based on GIS

The field servers in the cable tunnel are arranged in a partitioned section mode and communicate with the equipment in the corresponding section through a field bus mode. The field sensors collect the information of the field equipment and upload it to the field server, which then uploads it to the management and control layer via Ethernet. After the management control layer preliminarily processes the information, it issues control instructions to the field devices through Ethernet and via the field server,
and also transmits data to the remote monitoring center. In particular, the cable temperature monitoring system and the tunnel power supply system belong to field equipment, but the monitoring object of the system is the whole cable or tunnel. When collecting information penetrating through the whole cable tunnel, the corresponding subsystem server should be set up. Instead of accessing the field server in sections, the server should be directly connected to Ethernet.

3. Function realization of subsystems

Multi-sensor network cable tunnel monitoring system based on GIS is a multi-functional integrated monitoring system, which integrates cable temperature monitoring system, tunnel environment monitoring system, tunnel security system and tunnel video monitoring system. The system takes GIS map as the background, and reflects data information such as temperature, humidity, oxygen content, manhole cover signal, video signal and other data information in functional areas of the monitoring center in real time in the form of graphic signals or text attributes. The system only displays basic information when the cable tunnel is normal, and other information not directly displayed can be viewed step by step manually. Once the cable tunnel is abnormal, the system will immediately display the abnormal information on the screen, and start the relevant sound and light alarm to remind the attendants. In the tunnel virtual model of the system control center, the relevant information is visually presented. By clicking on the corresponding position of the electronic map with the mouse, the lighting, fans, pumps and other equipment in the tunnel can be monitored and controlled remotely, and the whole network of a map and pipe can be realized.

3.1. Cable Temperature Monitoring System

During the operation of cable lines, the temperature in local areas will increase, which will further aggravate insulation aging and even lead to fire. Therefore, the cable temperature should be monitored in real time to eliminate faults in time and ensure the power cable to operate at a safe temperature level [6]. At present, cable temperature monitoring methods mainly include electrical signal sensing technology and optical signal sensing technology. The technology of electrical signal sensing has high requirements for electromagnetic shielding of equipment because it has circuit channels and is vulnerable to electromagnetic interference from the environment. On the contrary, optical signal sensing technology has higher reliability. It detects optical signals. The signal channel is optical fiber and will not be interfered by electromagnetic interference from power equipment. The cable temperature monitoring system adopts the distributed optical fiber temperature measurement technology based on Raman scattering in the optical signal sensing technology, which can measure the temperature of the cable in real time and continuously [7]. The optical fiber is laid on that surface of the cable, and laser pulse are injected into the optical fiber to obtain Raman scattered light directly relate to temperature. Raman scattered light consists of Stokes light and anti-Stokes light with different frequencies. Stokes light is independent of temperature, while the intensity of anti-Stokes light varies with temperature. In the system, Anti-Stokes light is used as a signal channel and Stokes light is used as a reference quantity. In order to realize distributed monitoring of power cable temperature, the light intensity and laser transmission time of Stokes light and anti-Stokes light at each measuring point on the optical fiber are analyzed and calculated, and the real position of each signal point and the real-time temperature at that position can be calculated.

3.2. Tunnel environment monitoring system

Cable tunnel environment has great influence on the operation of power cables. In order to ensure the safe operation of cables and the safety of maintenance personnel, the environmental conditions in the tunnel should be grasped timely and accurately, and faults should be handled in time. Environmental factors in cable tunnels mainly include temperature, humidity, gas composition and water level of accumulated water, and their information can be acquired by setting up targeted sensors. The monitoring system of ambient temperature in tunnel can be improved by the existing optical fiber temperature measurement subsystem. The implementation method is to lay a temperature measuring optical fiber on
the top of the tunnel and connect it to a field server for information transmission and processing. Sensors for monitoring tunnel environmental humidity, gas composition and accumulated water level information select new digital sensors. Digital sensors with better performance are selected for monitoring environmental humidity, gas composition and water level information in tunnels. The comparison between traditional analog sensors and digital sensors is shown in Table 1. In order to realize intelligent control of field devices, environmental monitoring sensors and devices upload information to field servers in each section through field bus. After preliminary data processing, the field servers then issue control commands to the devices in the tunnel. For example, the control of tunnel ventilation system should comprehensively consider environmental temperature and humidity, gas composition, air flow velocity and other factors. This information is processed by the on-site server and finally determines the number of fans starting and stopping in the ventilation system; In order to realize the effective control of water pumps, it is necessary to consider the status of accumulated water in the field and the status of all kinds of water pumps. When there is a fire in the tunnel, the system will immediately start the fire alarm and extinguishing device to prevent the expansion of the incident. These data and information will be uploaded to the remote control center for storage and recording to realize manual remote control.

![Tunnel environment monitoring system](image)

**Figure 2.** Tunnel environment monitoring system

### 3.3. Tunnel security system

In the power cable line system, human damage and theft are the main factors causing cable losses. In order to prevent people from breaking into the tunnel and carrying out destructive activities, one is to strengthen manhole covers and ventilation openings for personnel to enter and leave. In addition, through the application of real-time monitoring technology, the status of tunnel entrances and exits should be monitored in real time. The implementation of monitoring technology is to set up electronic warning devices at each entrance and exit. The electronic warning device adopts passive infrared detection technology [8]. The working principle of passive infrared detection technology is to induce infrared rays emitted by human body through pyroelectric elements. When the pyroelectric element receives infrared radiation from human body and changes, it will cause charge imbalance and release charge outward. This voltage signal can be used to drive the alarm device after being processed. The electronic warning device is laid at the entrance and exit of a tunnel. Once the device senses an intrusion, it will give an alarm [9-10]. At the same time, the alarm information will be uploaded to the remote control center. In order to avoid false alarm, cameras are installed at the entrance and exit of the system to realize linkage with warning devices. When the alarm is received in the remote control center, people can call cameras to observe the scene remotely to further confirm the scene and improve the reliability of the security system.
3.4. Tunnel video monitoring system
In the daily maintenance of power cables, the traditional method is to use manual regular on-site inspection. This method is intuitive and effective, but it is time-consuming and labor-consuming, and may even cause harm to operation and maintenance personnel. The application of video monitoring technology can greatly reduce the labor intensity of operators and realize the efficiency and timeliness of tunnel inspection. In order to reduce the labor intensity of operators and realize the efficiency and timeliness of tunnel inspection, video monitoring technology is used in the daily maintenance of power cables.

Sensors installed in the tunnel can monitor the environment and various auxiliary facilities. By installing cameras at important positions in the tunnel, the entire monitoring of the tunnel can be basically realized. The on-duty personnel in the control center can directly observe the real-time condition of the tunnel site through remote video images, which greatly improves the maintenance efficiency of power cables. Considering the interference of magnetic field on video transmission, steel pipe shielding is used to prevent interference in the part of video cable transmission from camera to optical terminal.

4. Conclusion
Multi-sensor network cable tunnel monitoring system based on GIS is a multifunctional comprehensive monitoring system. Considering the factors of high-voltage cable and cable tunnel operation and maintenance, the system takes GIS system platform as the carrier, and integrates cable temperature monitoring system, tunnel environment monitoring system, tunnel security system and tunnel video monitoring system in a networked, digital and integrated manner. The system realizes full sharing of cable tunnel information and highly intelligent linkage of tunnel equipment, which plays an important role in ensuring safe and stable operation of cables and improving power supply reliability of power system.

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