Application of Monitoring System Based on Green Environmental Protection Cable Pipe Protector

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Abstract. In view of the current status of the monitoring system for cable conduit protectors, the green environmental protection and the monitoring system for cable conduit protectors are closely combined to explore the construction of an omnidirectional, multi-level and wide-coverage intelligent cable conduit protector monitoring system to coordinate the advantages of advanced scientific research, technology, instruments and equipment. Based on the research background, the paper briefly introduces the high-temperature superconducting cable monitoring and protection system, and systematically explains the overall function of this research software, frame structure design, communication implementation method, various data record analysis and fixed value research.

1. Introduction
Socio-economic development is rapid now, and the construction of urbanization must provide higher requirements for urban infrastructure. The so-called low-carbon life is mainly to advocate that humans must use low consumption and low pollution as a prerequisite in daily life, adopt more energy-saving methods, and reduce carbon dioxide emissions. This is the living environment of the people in the development process of the new century A basic principle and attitude of living. For the power grid, it is an important part of urban public facilities. The problem that needs to be solved now is how to coordinate the contradiction between the growing urban power load and the human living environment, environmental protection and urban protection. In order to better solve this problem, it is necessary to use the power transmission method of cable lines, and at the same time combine the urban power grid pipeline and pipeline network, which has become the characteristics of modern urban power grids, especially large international urban power grids.

The connecting cable line is a transmission power supply device used to connect the distribution transformer to the secondary knife box. At present, there are two types of connection cable lines commonly used in oil production plants: the first is aluminium core connection cable lines, and the second is copper core connection cable lines. From spring to autumn, due to the relatively strong wind force, the phenomenon of line wear and line phase loss often occurs, and even motor and transformer burnout accidents have caused the pumping unit to shut down and fail to produce normally, affecting the completion of crude oil production tasks. A sound cable pipeline monitoring system can meet the operating standards of the smart grid, and can provide high accuracy conditions for the distribution of electrical energy. In particular, the system has good real-time dynamic load capacity and online status
monitoring ability, which can ensure the smooth and stable operation of the cable pipeline, reduce the cost of operation, and effectively avoid the occurrence of failures.

2. The basic structure of the high-temperature superconducting cable protection system
The entire superconducting cable system is divided into four parts: superconducting cable body, superconducting cable terminal, superconducting refrigeration system, and superconducting cable monitoring and protection system. The superconducting cable body is a composite body containing superconductor, inner support tube, thermal insulation layer, electrical insulation layer, cable shielding layer and protective layer; the superconducting cable terminal is composed of superconducting cable, high voltage busbar and liquid nitrogen refrigeration system. The interface is responsible for the task of transitioning the temperature and potential of the superconducting cable; the superconducting refrigeration system is responsible for maintaining the low temperature environment necessary for the normal operation of the superconducting cable. It consists of a refrigeration unit, a liquid nitrogen pump, and a liquid nitrogen storage tank; The cable monitoring and protection system is responsible for ensuring the safe operation of the high-temperature superconducting cable system in the power grid, and providing as much detailed and detailed field operation data as possible. The superconducting cable monitoring and protection system is different from the traditional relay protection system [1]. In addition to the protection function, it also involves online monitoring of operating status, continuous recording of steady-state operating data, and recording and analysis of fault data. According to the application characteristics, the superconducting cable monitoring and protection system adopts the layered structure as shown in Figure 1.

Figure 1. Structure of superconducting cable monitoring and protection system

Figure 1 mainly includes four parts: upper layer research machine (local machine), remote monitoring machine (remote machine), data acquisition and protection unit (lower machine) and isolation transformation layer. Among them, the upper-level research machine mainly completes the operation and debugging research of the device, online monitoring of operating parameters, storage and analysis of recorded data, and the formation and printing of fault reports, and communicates with the remote monitoring machine (remote machine) in the main control room through communication. The lower layer machine forms an independent system by itself, designed according to the requirements of relay protection, and only interconnects with the upper layer machine through the communication interface to improve the reliability of its operation. The lower layer machine adopts dual CPU parallel working mode, that is, the front-end data acquisition board uses a digital signal processor (DSP) as an intelligent component to complete the analogy / digital conversion research and calculation of basic parameters; the main CPU board is a highly integrated 486 single board. The computer interacts with the DSP board through the dual-port RAM and is responsible for fault detection and data storage control. The isolation conversion unit performs isolation conversion on the input signal [2].
3. Modelling of the current in the ground wire of the metal sheath of the cable
The electrified power supply system mainly provides uninterrupted power supply to the loads along the power grid, and has the characteristics of many access points and small loads. Generally speaking, the 10kV three-core cable laid along the grid is laid parallel to the grid within 100m from the grid. When the two ends of the cable are grounded, the transient overvoltage appearing in the sheath is 10% of that when the single end is grounded, which can effectively prevent the impact of overvoltage or power frequency overvoltage from jeopardizing the safe operation of the cable. The current of the cable grounding wire in the electromagnetic environment of the power grid has obvious periodicity and fluctuation and will cause loss of the metal sheath, which will aggravate the heating of the cable and the aging of the insulation. In the long run, it may even cause insulation breakdown or cable burnout. The cable head is mostly located in the cable junction box or box transformer. The thermal conductivity of the air is much lower than the soil. The temperature at the cable head is higher than the temperature of the cable buried in the soil. The superposition of various factors causes the power cable head of the electrified section of the power grid to be hotter than the general power cable, and the probability of burning is greater [3].

3.1. Influence of grid current on cable sheath
The power supply system of the power grid is generally composed of a contact grid and a power grid. The power penetrating lines are generally laid in parallel along the power grid, and the alternating magnetic field generated by the contact network will generate a large induced voltage at the cables and pipes laid in parallel along the line. For the single-line direct power supply grid, the electromagnetic induction voltage calculation model based on the grid model is used to obtain the induced voltage of the grid current on the cable sheath. When the power system and the feedthrough cable are normally charged, the contact grid and the power grid will generate an induced voltage on the cable sheath. The induced voltage on the sheath is the superimposed result of the induced voltages generated in the three loops, of which “contact network-ground” is the first loop, and the loops between the earth and the two power grids constitute the “grid 1-ground” 2 loops and the 3rd loop of "Grid 2-Ground". The induced electromotive force of the cable sheath is derived from the coupling relationship of the three loops as follows

\[ E_n = 2\pi fM_n I_G \]  \hspace{1cm} (1)

In the formula: \( M_n = (4.64l_g(D/d_n) - j\pi/2) \times 10^{-4} \) is the mutual inductance coefficient of the catenary and cable sheath, \( D = 0.2085/\sqrt{f \times 10^{-5}} \) is the equivalent ground return depth, \( \sigma \) is the ground conductivity, \( d_n \) is the parallel proximity distance between the catenary and the cable; \( l \) is the contact net Parallel length; \( I_G \) is the induced current in the middle. And because the current of the grid and the return flow are always in the opposite direction, each current is obtained as

\[ I_{G1} = I_{G2} = 0.5I \]  \hspace{1cm} (2)

In the formula, \( K = Z_{12}/Z_2 \) is the inductance, \( Z_{12} \) is the transimpedance per unit length (\( \Omega \) / km) between the “contact network-earth” loop and the “-earth” loop, and \( Z_2 \) is the self-impedance (\( \Omega \) / km). The total induced potential on the cable sheath is

\[ E = \sum E_n \]  \hspace{1cm} (3)

Take \( f = 50Hz, \ \sigma = 1S/km, \ Z_2 = (0.198+0.56j)\Omega/km, \ Z_{12} = (0.05+0.319j)\Omega/km \), \( I = 1000A \), to obtain the induced voltage curve of the sheath under different parallel lengths and parallel proximity
distances of the power cable and the power grid when the metal sheath is grounded at one end, as shown in Figure 2.

![Figure 2. Induced voltage of cable sheath](image)

It can be seen from Figure 2 that the induced voltage on the cable sheath is larger when the single-end is grounded. As the length of the cable increases, the induced voltage value on the cable sheath shows an upward trend; the parallel proximity distance between the cable and the power grid is within 100m the change is obvious. As the parallel approach distance increases, the induced voltage value shows a downward trend. When the cable length is 1km, the induced voltage of the cable sheath 100m away from the power grid can reach 100V [4].

3.2. Impact of ground return on cable sheath

The distribution of ground return under direct power supply is shown in Figure 3.

![Figure 3. Schematic diagram of return flow distribution in direct supply mode](image)

In the single-line electrification section, the ground return in direct power supply mode can reach 30% to 40% of the grid current. As shown in Figure 4, the current flowing through the protective layer is the largest when facing the grid current into the location.
Figure 4. Schematic diagram of the effect of ground return on the adjacent cable sheath

The expression of the potential formed by the stray current near the cable ground to the potential at infinity is

$$U = \frac{\rho I \gamma}{2\pi} \Omega(\gamma X, \lambda Y)$$

(4)

Where: $\rho$ is the soil resistivity; $\tilde{I}$ is the grid current; $\gamma$ is the propagation constant of the "shield-earth" loop; $y$ is the parallel distance between the buried power cable and the rail; $\lambda$ is the shielding coefficient; $\Omega(\gamma X, \lambda Y)$ is a special function, The value can be obtained by looking up the table. Take $I = 1000 \ A$, $\gamma = 1.35 \times 10^{-3}$, $\lambda = 0.5$. Obtain the voltage across the power cable sheath at different locations under different soil resistivities, as shown in Figure 5 [5].

Figure 5. The resistive coupling voltage of the cable sheath
It can be seen from Fig. 5 that the distance beyond 10m from the power grid is no longer the main reason for the potential of the grounding end of the cable sheath of the penetrating line. At this time, the influencing factors of the potential of the cable sheath are mainly the magnitude of the ground current and the earth resistivity. The earth resistivity of a certain area is considered to be fixed, so the key influencing factor is the magnitude of the ground return.

3.3. Analysis of abnormal cases of cable pipeline monitoring system

3.3.1. Temperature monitoring. The cable intermediate connector is an important connection part of the cable line. During the operation of the cable, the intermediate connector is often made of poor quality or the crimping is not tight, resulting in excessive contact resistance, so that the cable head is overheated and burns through the insulation layer, resulting in fire and affecting the power supply reliability. Real-time online monitoring of key parts through contact-type (or infrared temperature-sensing module) temperature-sensing module (the number of monitoring cables required by the root user to install different numbers of modules), when the temperature is abnormal, it immediately alarms, and uploads real-time data for overheat warning data analysis Function, find and eliminate hidden dangers caused by fever in time to avoid accidents.

3.3.2. Partial discharge of cable. XLPE insulated cables are widely used in urban medium- and high-voltage power grids. In 2013 and 2014, the 110kV and above XLPE cables centrally tendered by the State Grid Corporation each year exceeded 1000km. Because of the inherent electrical properties of cross-linked polyethylene cables, the experimental means for their cable circuits are very limited. Common experiments include DC withstand voltage test and ultra-low frequency cross-linking withstand voltage test, but the DC withstand voltage test is more destructive to the cable body insulation, the cross-linking test equipment is relatively bulky, and the test efficiency is low. The technologies of online cable monitoring mainly include DC superposition method, DC component method, and partial discharge detection method. Especially the partial discharge monitoring method is favoured by experts and scholars at home and abroad. However, early local electrical measurement will interfere with the scene and increase the difficulty. At present, on the basis of the continuous maturation of information technology and electronic technology, the signal location and auxiliary partial discharge functions of the level detection technology have also been widely used.

3.3.3. Cable temperature detection. In cable temperature monitoring, thermistor temperature measurement and dare to ask cable-type temperature measurement and optical fibre distributed temperature measurement are currently the most common temperature monitoring methods. Among them, independent wiring of the thermistor temperature measurement will cause wiring disorder and cause damage to the original. And cannot complete the self-test, increase labour; and the temperature-sensing temperature measurement cannot be used repeatedly, cannot measure the temperature in real time, cannot find the temperature change of the cable, the fault detection function is poor; fibre distributed temperature measurement is currently the most practical temperature measurement. The system has lower cost and better positioning, real-time recording and real-time temperature measurement functions [6].

4. Design of cable monitoring system

4.1. Software design
Develop and build a complete and operable distributed software system that can monitor the data of the stored detectors in real time and can send out alarm information in time. It is the main station composed of the host server and the analysis and monitoring software that is responsible for analysing and processing the data. GPRS wireless communication network is used to transport data between the data collection terminal and the main station. The system platform comprehensively explores the data
obtained by the monitoring main station, warns to identify, and observes the operation of cable trenches and cables at any time. Researchers can obtain the latest information and can adjust the work at any time. Not only does it increase work efficiency, it also reduces problems in cable ducts. The software webpage has restrictions on the conditions of the logged-in personnel. It has the capabilities of data report search, alarm time display and time search. It also works with the GIS global geographic information system to accurately work the specific location of the trench well. Mark each cable well to ensure unique data. It is expressed in the form of map, which is convenient for graphical search, and can detect the information in the ditch well and search in time. The software has the ability of parameter setting and debugging, and can change the alarm parameters according to seasonal changes or detection changes.

4.2. Hardware design of cable monitoring system

4.2.1. Data collection terminal. The facilities of the data collection terminal are mainly used for collecting sensor data, registering and registering the sensor, generating automatic configuration files, powering the sensor according to the actual situation, etc. In addition, according to the communication regulations of IEC60870-5-104 The information is packaged and transferred to the master station system through EPON and through the network. And can also complete the remote-control commands of the master station system. The facility of the data collection terminal has an official telephone interface.

4.2.2. Network equipment. Network equipment is mainly divided into data acquisition, backbone, WEB, deployment and other switches, through EPON and router to achieve communication between computers and equipment.

4.3. Functional design of data acquisition terminal

Configure the communication requirements and standards according to actual needs. Generally, the communication protocol of IEC618_50 or IEC60870-5-104 is used; in addition to the battery, 380V AC power supply and 220V / 110V AC and DC power supply methods, there are many other methods. In addition to cables, optical fibres and GPRS data transmission media, it also contains many other media sensors and configuration files that can be automatically generated, and the loading device of the master station system can also be automatically run. Geographic information data can be automatically generated, and the master station system can also automatically update GIS information. You can use the web method to set artificial sensors or equipment, which can make manual measurement and maintenance more convenient; there is an Ethernet network and RS232 / RS48_5 interface, and there is an RS232 or Ethernet maintenance interface; it can realize the state quantity and analogy quantity. Collect, receive and complete remote control commands; can receive timing signals from the master station.

5. Data analysis

Sampling tests were mainly conducted on the cable head sheath voltage, ground wire current, and outer sheath temperature. The test data is shown in Table 1 to Table 3. According to the data in Table 1 and Table 3, the average absolute errors of the three modules of voltage collection, current collection and temperature collection of this device are 0.229, 0.357 and 0.557 respectively. The test result proves that the sampling data of this device has high reliability. The visual manifestation of abnormal heating or even burning of the cable head is that the temperature of the outer sheath is too high. Considering the influence of the cable head grounding wire current, outer sheath temperature, sheath induced voltage, ambient temperature, and humidity on the cable head outer sheath temperature, multiple linear regression treatment is performed on the cable outer sheath temperature. Using the monitoring data returned by the device in real time, extract 1 649 sets of data obtained in any time period, and use MATLAB software to do multiple linear regression. The simulation results are shown in Figure 6.
Table 1. Voltage data

| Oscilloscope measured voltage / V | Monitoring device measured voltage / V | error  |
|----------------------------------|--------------------------------------|--------|
| 35.6                             | 35.5                                 | -0.1   |
| 44                               | 44.2                                 | 0.2    |
| 52.8                             | 52.7                                 | -0.1   |
| 72.6                             | 73                                   | 0.4    |
| 87.5                             | 87.9                                 | 0.4    |
| 102.9                            | 103.1                                | 0.2    |
| 120.3                            | 120.1                                | -0.2   |

Table 2. Current data

| Ammeter measured current / A | Monitoring device measured current / A | error |
|-----------------------------|--------------------------------------|-------|
| 10.2                        | 10.5                                 | 0.3   |
| 26.3                        | 26                                   | -0.3  |
| 35.4                        | 35.5                                 | 0.1   |
| 43.8                        | 44.2                                 | -0.4  |
| 54.7                        | 54.2                                 | -0.5  |
| 77.5                        | 77.8                                 | 0.3   |
| 83.4                        | 84                                   | -0.6  |

Table 3. Temperature data

| Temperature measured by thermometer / ℃ | Temperature measured by monitoring device / ℃ | error |
|----------------------------------------|-----------------------------------------------|-------|
| 20.1                                   | 22                                            | 0.9   |
| 29.6                                   | 28.6                                          | -1    |
| 38.4                                   | 37.8                                          | -0.6  |
| 47.7                                   | 47.5                                          | -0.2  |
| 57.2                                   | 57.8                                          | 0.6   |
| 63.2                                   | 63.8                                          | 0.5   |
| 75.2                                   | 75.1                                          | -0.1  |
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Figure 6. Multiple linear regression results

6. Conclusion
The thesis has developed a multi-parameter online monitoring device for the operation status of the cable head using ATmega1280 as the control chip. By comparison with the operating environment parameters of the cable, it is sent when the current of the cable ground wire, the temperature of the outer sheath or the induced voltage of the sheath exceeds the set value. The alarm information is convenient for the staff to understand the operation status of the cable head in time. At the same time, the staff can judge the operation status of the cable based on the historical record information of the cable head status, so as to early warning, adjust the cable load, and formulate a reasonable cable head maintenance plan.

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