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Intelligent Online Monitoring and Anti-theft System for Underground Cables

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Abstract. Based on the characteristics of power cables, an intelligent online monitoring system is constructed for failure detection and positioning. The implementation idea is illustrated and the main functions of the system are introduced in this paper. When power cable is destroyed or stolen, the system will send warning messages to alert the power management department. The actual applications show that the system has the advantages of convenience, low cost and high reliability.

Introduction

With rapid development of power line network, underground cables play more and more important role in power distribution systems. Although their advantages are obvious, e.g. lower influence on natural environment, less land occupation and higher power supply reliability, underground cables are often suffered from frequent damages in application, as a result of which service life of power cables will be shortened, therefore it is important to ensure the cables run in good status.

Generally, current underground cable protective measures are mainly as follows:

- Assigning to agents the regular inspection, special inspection and key project inspection.
- In order to remind the operator of careful cable protection, warning signs on important spots are placed.
- Buried pipes, tunnels and other channel forms with better anti-external force capability are used widely to substitute those with worse anti-external force capability, such as direct buried ones.

The above measures are of high human and material cost, but low degree of automation and intelligence, which results in poor anti-external damage effects. At present, intelligent cable anti-theft technique has developed gradually. On the bases of traditional cable laying process such as cable bury, deep bury and concrete package, high-tech anti-theft means would probably be the trend in future.

Requirements analysis

Based on investigation, it is very urgent for power management department to develop an intelligent online monitoring system with which power transmission failures will be detected immediately and their positions can be determined accurately. The following objectives are achieved in the system.

- 24 hours real-time online monitoring of power distribution network
- Accurate positioning of cable failure locations
- Remote instant alerts
- Convenient installation and maintenance

Implementation idea

Underground cables are triple core cable including three core wires and shield layer which is comprised of a copper shield and a steel armor. The underground cable is laid as shown in Fig. 1, wherein substations A, B are connected by the cable, in which a series of distributed equivalent capacitors (C1, C2, …, Cn) are formed by the long core wires and the shield layer. For the purpose of security, both ends of the copper shield and the steel armor are grounded respectively.

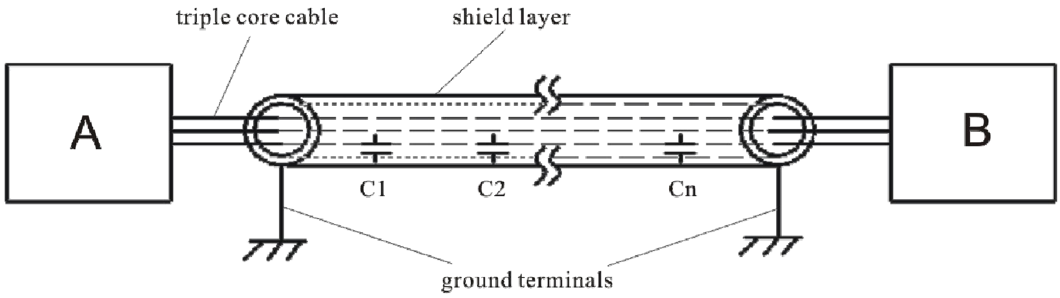

Fig. 1 Laying manner of the underground cable

The wire cores are applied with AC voltage of 10KV/50Hz when the cable is working. Transmitted signals will leak and attenuate due to the distributed capacitances existing between core wires and the shield layer. When detecting the damaged area, it is the key point to input a certain detective signal into the cable without changing the cable operation and its ground connection.

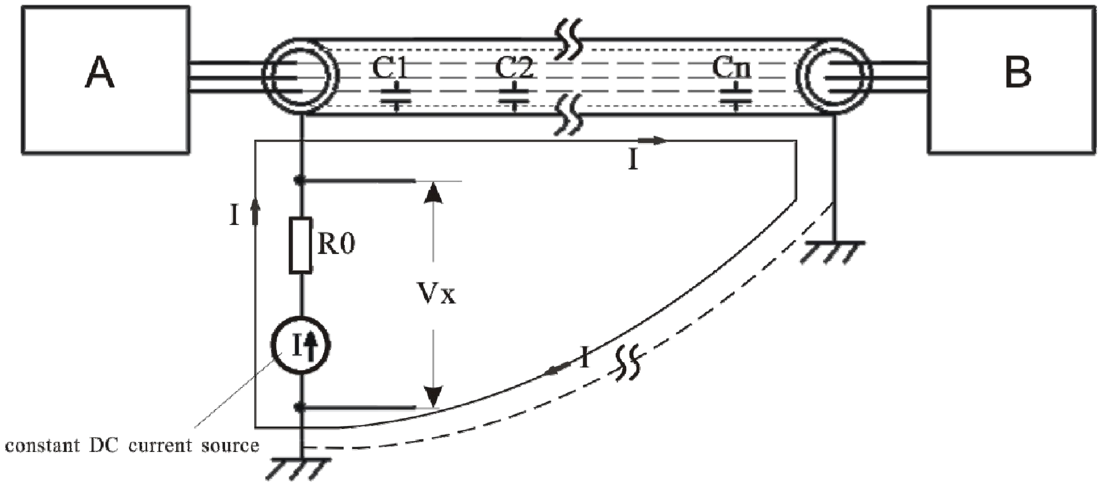

Fig. 2 Implementation idea of the system

The implementation idea is shown in Fig. 2, wherein electric power is transmitted by the cable between substations A and B. With both ends of the copper shield and the steel armor reliability grounded, a closed circuit composed of the steel armor and the earth is formed. The resistances of the circuit consists of distributed resistances of the steel armor and the copper shield on length, ground loop resistance of the ground terminals and resistance of a given standard series resistor R0. The standard resistor R0 is accessed to a voltage detecting circuit, to which an alarm output circuit is parallelly connected. In this system, the voltage detecting circuit is used for voltage detection across the resistor R0, the corresponding equivalent circuit of which is illustrated in Fig. 3.

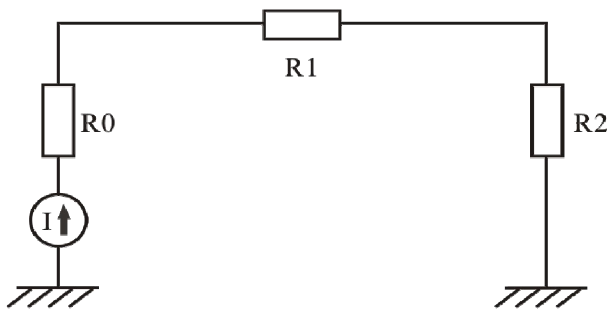

Fig.3 Equivalent circuit

When a constant DC current supplied by constant current source is fed into the voltage detecting circuit, there will be a potential difference between the two ends of the resistor R0, which can be measured by the voltage detecting circuit and the value of which is marked with V. Since both ends of the steel armor are grounded when the cable is in good status, the value V is determined by resistors R0, R1(distributed resistance of the steel armor on length), R2(grounding resistance) and the input constant current. By contrast, when a failure occurs, the steel armor will become ungrounded at one end and the voltage detecting circuit will be disconnected. Correspondingly, an open circuit voltage value Vx of the standard resistor R0 can be detected. Obviously, a definite failure can be determined by comparing the two values Vx and V, whereas an approximate location of the failure can be positioned by calculating the ratio of V to Vx.

The constant DC current, as the detection signal, will not be affected either by the distributed capacitance of the cable or by the cable length. Real-time online monitoring of the underground cable failures can be achieved through this method without the cable grounding mode being changed.

System framework

General framework of the intelligent online monitoring and anti-theft system for underground cables comprises an anti-theft device, a remote monitoring subsystem and a server acting as the data center, wherein the anti-theft device, as is shown in Fig. 4, is composed of an ARM processor as the overall controlling component responsible for receiving and sending controlling instructions, a constant DC input module for generating and feeding detective signals into the cable ground loop, a signal processing module for detecting the voltage of R0 and amplifying the signals, a fault diagnosis module for determine whether a failure is occurred and a GSM alarm module for sending alarm SMS when needed to inform a cable failure.

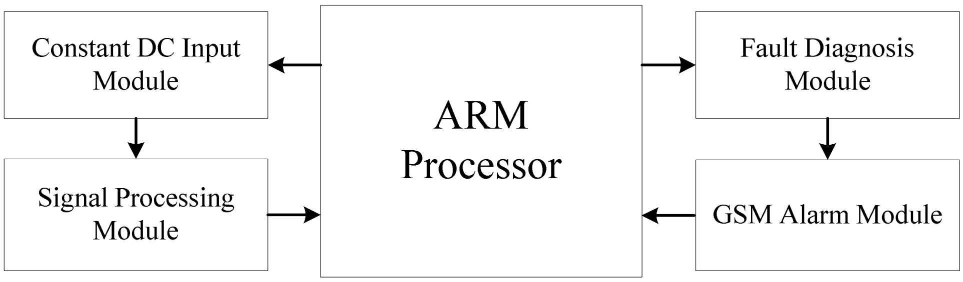

Fig. 4 Framework of the anti-theft device

Anti-theft devices, each installed in one of the distributed substations, are connected by branches of underground cables and provided with network communication interface by which the anti-theft devices can communicate with the data center, so that a local area network composed of anti-theft devices, cables and the server is built up. The remote monitoring subsystem installed in the data center where the status information of the branch cables are aggregated, analyzed and stored can monitor the running status of each device in real time.

Main functions of the system

Device management. The information of anti-theft devices installed in substations can be managed in this system, such as adding, querying, modifying and deleting the device(s).

Cable damage alarm. Running status parameters of the substation cables can be acquired in real time in the system. By monitoring feedback current in the detecting circuit, which branch cable encounters with damage or theft can be determined and the damage position can be calculated accurately as well. Besides, managers of the corresponding substations will be alerted by both screen popup and SMS messages.

Alarm message tracing. In case the messages fail to be received by intended recipient, the alarm messages will be traced after being sent out, which will be resent automatically by the system if there is no reply from the recipient. The same alarm message which is still not replied after being sent three times will be sent to the direct superior of the recipient. With such tracing system, it can be guaranteed that any one of the failures will be handled without delay, so as to institutionally prevent failures from worsening.
Report analysis. All alarm messages and running information will be recorded automatically in this system, as well as system operating information of all login users. Report analysis function is provided to generate a variety of reports based on requirements of electric management for managers to inquire and analyze, and assist in improving management ability.

Conclusions

The intelligent online monitoring and anti-theft system has been put into practical application, and it has been proved that the following benefits are brought to the power suppliers.
Cost saving. Through intelligent monitoring and remote controlling, maintenance manner of the power system is changed and labor intensity of inspection is reduced, so that corresponding labor and management costs are reduced effectively.
Loss reduction. Failures are prevented from further extension by alarms on cable damage and theft, and criminal actions of theft and stealing are deterred as well, thereby reducing the loss of power equipment.
Creditability improvement. Since the maintenance of power system is institutionalized, dependence of maintenance on personnel quality is plummeted correspondingly, so that maintenance quality is improved and stable running of the power system can be guaranteed, thus improving social creditability of the power suppliers.

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