A SMART CABLE MANAGEMENT SYSTEM IN SUPPORT OF THE SMART CITY

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ABSTRACT

With the promotion of the smart city and the development of smart distribution network, intelligent management of the vast, expensive power cable network is attached with growing significance. This paper proposes a novel, intelligent cable management system, of which the aim is to improve the operational and maintenance effectiveness and to support smart cities. Firstly, it discusses the challenges to the current power cable maintenance and management practice before the term of intelligent cable management is defined. Secondly, the framework of the intelligent cable management system is presented along with the supporting information platform based on Geographical Information System (GIS). Using cloud sharing technology, locations of the cable circuits, gas pipes, water pipes and other underground pipelines are displayed on the same GIS platform, based on which these underground pipelines can enjoy information sharing, collective planning, operation and maintenance. Thirdly, Internet of Things, Mobile Internet, Big Data and other new information technologies are used to improve condition monitoring and to evaluate remaining service life of power cables, in order to realize an orderly and optimal replacement of the power cables. Also the system can enable other utilities to plan systematically their underground pipeline network construction and replacement. Finally, taking the Chinese City of Suzhou's management system as an example, the paper illustrates the utilization of the novel, intelligent power cable management model to support smart city construction. The case study shows that with the aid of Cloud Sharing technology，Big Data and other IT technologies, power cable network maintenance and management practice is significantly improved and the cable network becomes more reliable. The mutual benefit among the different utility companies is significant because of the reduced third party damage, leading to enhanced energy supply security and public service within the smart city.

INTRODUCTION

Power Cables have been increasingly adopted in China's power networks due to aesthetics concerns and the associated high reliability [1] [2]. With the traditional power cable management system, the fact that the existing cable information is not shared with other underground pipelines becomes a constraint of the smart city development. For example, third party damages often occur to the underground pipelines due to the high density of construction work that has been happening in China in recent years. In terms of power cable network maintenance, it's difficult to provide early warning in the network operation due to a shortage of effective analysis methods, leading to reduction in power systems reliability. Therefore, it is imperative to improve the power cable management mechanism and to upgrade its intelligence level.

There has been a shortage of report on novel power cable management systems. It is with this background that this paper proposes a intelligent cable management system, starting with a definition of the concept. Afterwards it builds an information platform supporting intelligent management. Finally, it introduces the implementation of the power grid intelligent cable management system in the city of Suzhou, China.

CONCEPT OF INTELLIGENT CABLE MANAGEMENT AND FRAMEWORK DESIGN

Concept of Intelligent Cable Management

The concept of intelligent cable management could be referred to as follows: Based on the application of new information technologies to monitoring of power cable equipment, information such as cable partial discharge, circulation current, body temperature could be acquired online; With these information the health or condition of power cables could be evaluated intelligently; With the aid of a highly effective GIS management system, the fragmented information of all underground pipelines could be shared with other utilities, thus fulfilling the goal of One Map (GIS) Manages All Network (Underground pipelines). While enhancing the reliability of the power supply, it can also aid all relevant organizations to manage urban underground pipelines with significantly improved efficiency and to reduce the failure rate of network operations due to reduced third party damages which contribute to nearly half of the power cable failures in China.

Features of Intelligent Cable Management

Smart Condition Monitoring

Intelligent cable management forms an integral part of the smart city. Power cables exist in the underground, along with other pipelines, are characterized by concealment, wide-reaching and coexistence. Therefore, information related to power cable operational and health status and its ambient environment are key to their intelligent management. By installing sensors along the power cable circuits, real-time monitoring over key indicators such as partial discharge, grounding circulation current, cable temperature and the transmission capacity as well as water level, gaseous content and entrance security of the channel where power cables are installed could be realized. Furthermore, it could achieve intelligent visualisation and automatic or smart data processing with regard to the key variables of power cables.

Power cables, are regarded as important urban facilities and the Life Line of any modern cities as they are essential in distribution of electrical energy. The inter-connection among power cables, and their interweaving with other underground pipelines determine that the intelligent cable management, smart management of other pipelines and smart city are not independent systems. Instead they are inter-dependent and should be coordinated by internet technology to enable real-time and continuous exchange of data information.

Intelligent Applications

The intelligent cable management systems will inevitably witness more intelligent applications with the development of mobile internet. By smart sharing of information about the operational state and condition of other underground pipelines nearby, hidden threats could be alerted to operators of the surrounding power cables. Big Data Analysis Technology could be adopted to detect the operational condition and risks of power cables comprehensively. In addition, Digital Urban Management technology could be exploited to coordinate the operation and maintenance of power cables with other underground pipelines.

Framework Design of the Intelligent Cable System

As demonstrated in Fig.1, there are four levels in the framework of the smart cable management system, namely equipment level, perception level, platform level and decision level. The equipment level refers to the objects, which are cable assets including the cable circuits, cable accessories and the surroundings of their installations in this case, under smart management; The perception level refers to the applications which help to collect, pre-process and transmit data and information relevant to the cable conditions by Internet of Things. This may include the application of various types of sensing devices such as those for monitoring of grounding circulation current, and partial discharge; The platform level is central to smart cable management as it combines the functions of big data storage and various of analysis. In addition, it should be able to process the data collected from the perception level or those from smart city interactions. Serving as the core of the framework, this level forms the basis of the decision-making level; the decision-making level is the foothold of the smart cable management system and is responsible for making informed decisions based on analysis of the results from earlier levels so as to realize power cable smart management.

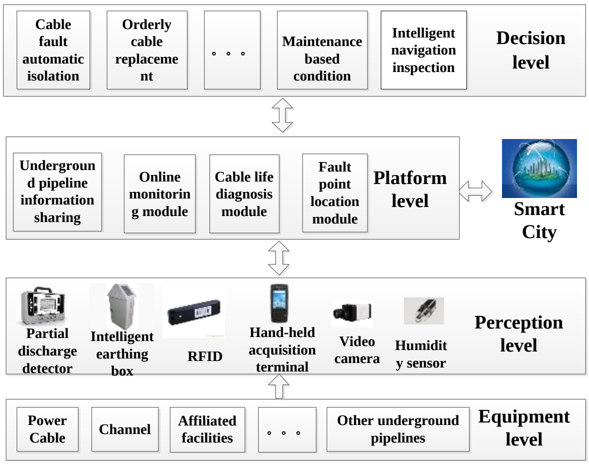

Fig.1 The framework of the intelligent cable management system

MANAGEMENT SYSTEM IN SUPPORT OF SMART CABLE BASED ON ArcGIS

This chapter presents the three-dimension system in support of smart management based on ArcGIS and designs its overall structure, database and functions.

Implementation of the Proposed System

The management system was implemented in the open developing environment of Visual C# + ArcGIS for Silverlight SD. The system consists of four layers: information interaction layer, data layer, business layer and platform layer. Information interaction layer has interfaces which receive data from the power systems Production Management System (PMS), SCADA system and the online monitoring equipment under an unified communication protocol and it provides the contents of Data Set to data layer via the data exchange platform; The data layer establishes a normalized database using an unified data criteria which contains attribute data obtained from those online monitoring and in-service tests, based on previously established fault signatures; Business layer offers various kinds of business applications such as the basic account management, online monitoring data replays and analysis, comprehensive information sharing with other pipeline management systems in addition to estimation of remaining service life for power cables. The platform layer covers a two-dimensional GIS platform based on Web, three-dimensional graphics platform and mobile clients.

System Database

The system database was established with the SQL Server 2012 database platform where the SQL Server 2012 and ArcSDE data search engine from ArcGIS space data are integrated to allow storage of data attributes, location and operational information. All data are unique and secure.

Attribute Database

Attribute database could be classified into cable circuits, other underground pipelines, power substation and telecommunication equipment, among which a cable circuit is mainly attributed by information including the cable circuit itself, the cable channel and cable accessories. For details, its data table covers the following columns: double names of the circuit, voltage and current rating, the terminal for receiving electricity, the terminal for distributing electricity, power cable manufacturer, type, length, section surface and operation date etc.

Location Database

The location database presents information including the geographical maps, surface structures, cables and location information of other underground pipeline in vector date structure, which can facilitate the cross-linking and invoking of the system. Among them common data involving basic map and images usually adopts ArcGIS Tile Service for interface invoking. Space and attribute database are stored separately, and the cross-linking between them is established by cross-indexed files.

Maintenance Database

The manitenance database mainly includes defect information, outage test data, online monitoring data, in-service test data, information on fault features and so on. Defect information and outage test information are acquired from periodically carried out routine inspections, while online monitoring data and in-service test data contains partial discharge, sheath circulation current, temperature of the cable and its accessories, current capacity, water level of the cable channel, gaseous content and so on. Information on fault features primarily contains fault diagnosis data, phase revolved patterns of partial discharge and data related to condition monitoring or test devices.

Constitution of System Function

Assets Management of Power Cable Equipment

The functions of asset management over the equipment include data browse, query analysis, data editing, statistical analysis, control module, where life cycle management is implemented of which the functionalities range from planning, designing, construction, equipment maintenance to decommissioning.

Information Sharing of Underground Pipelines

By superposition and integration of location layers along with the cloud share technology, mass data could be transferred to the public cloud terminal and forms a private cloud of power cable, where interactive data could be produced in the system serving as a Cloud Platform. In this sense, the underground pipelines could be shared and applied on one map. Sharing of layered data and categorized information ensures data security of the pipelines and consequently, pipeline information would not be isolated any more.

Online Monitoring and Smart Detection

According to the prior established knowledge on power cable operations, the system constructed parameter database about power cable surface temperature, the sheath circulation current, partial discharge, channel water level, man-hole conditions, video monitoring and so on. In the meanwhile, it established a multi-parameter mathematical model for condition diagnosis over power cables by extensive integration of historical data of online monitoring system and the real-time data. Applying big data technology into the evaluation of power cable condition diagnose, it generated a differentiated inspection strategies intelligently.

Other Functions

Furthermore, selection of power cable circuit and man-holes and planning of the cable channel paths could be completed by the system. The system allows development of new function modules on the actual demands under the principles of practicability, perspectiveness and expansibility.

CASE STUDY OF INTELLIGENT CABLE MANAGEMENT SYSTEM

This section introduces how the smart cable management system supports the development of the smart city in Suzhou, China. In Suzhou power supply company, there has been three development phases when the company embarked on the smart cable management project. The first phase focused on the three-dimensional surveying and mapping of power cables and cable channels, where power cables and other underground pipelines are displayed and managed on the same map. The result contributes to explain Where Are the Power Cable, while the second phase aimed at improving the coverage of online monitoring devices, answering the question of How do the Conditions of the Power Cables look like. In the third phase, big data analysis technology was exploited to handle the mass monitoring data so as to evaluate the remaining service time of power cables which help to illustrate When to Replace the Power Cables.

Rapid Location of Cable Fault

Take a recent incident of a power cable failure and the follow-up repair in Suzhou for instance, the developed system was applied with excellent effectiveness in the rapid location of the cable fault. The fault cable was Circuit 239 in Suzhou Industrial Park. The electrical distance between the fault point and the measurement point amounts to 286 meters. In the mobile terminal of the developed system, information about the cable man-hole closest to the fault spot could be demonstrated accurately less than one minute. This rapid fault point positioning enabled the maintenance engineers to obtain map reference, path-finding to the failure location and carry out discharge sound detection and positions the fault in one minute. The smart cable management systemsignificantly improved the repair efficiency.

Intelligent Navigation for Inspection of Cable Power

The developed system could guide maintenance engineers to inspect power cables in a more precise way with the aid of the system navigation. Take Gangjin Circuit for instance, the red full line in Fig.2 shows the automatically planned paths in the system which could guide the inspectors for circuit patrol, during which GPS is for real-time positioning so as to playback the inspection tracks. In Fig.2, the red dotted line refers to the actual patrol path of the inspectors and the system could compare the planned and actually walked paths automatically, thus realizing intelligent control over the circuit inspection quality.

Fig.2 The supervision of cable circuit patrol

Three-dimensional Information Sharing of Underground Pipelines

Accurate three-dimensional data of power cables and cable channels provides the foundation to disclose any ongoing construction work precisely and to reduce third party damage to underground power cables. Along with the three-dimensional modeling technology, three-dimensional application was achieved. In addition, the Suzhou power supply company is in the process of actively integrating the intelligent cable management system into smart city project. Through the cloud share technology, the urban map of Suzhou industrial park could be shared, where the information about other underground pipelines including gas, telecommunication and water supply is displayed as well. Therefore, third party damage to one another between power cables and other pipelines could be reduced. With the information shared, the cross distance between the parallel pipelines could be ascertained, leading to effective hazard checking. Just as demonstrated in Fig.3, the parallel distance between the power cable and the gas pipe is 6.17 meters which meets the requirements of regulations.

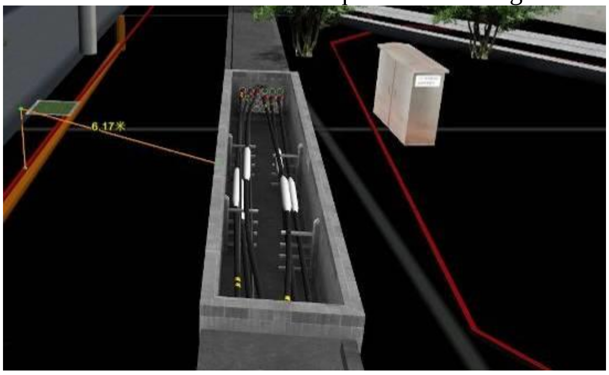

Fig.3 Information sharing between cable lines and other underground pipelines

CONCLUSION

This paper proposes the construction of smart city through smart cable management. By integrating different types of power cable monitoring devices and applying big data technology into monitoring data analysis, multiple functions of the system could be achieved such as inspection and maintenance of power cables, rapid online positioning of the fault location, emergency response based on three-dimensional live display, leading to significantly improved reliability of power supply due to reduction of failure rate of underground pipelines.

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