HV Cable Intelligent Sensing IoT Technology and Application

Tianyu Yang, Hai Li, Yunjie Zhou, Jialiang Yuan, Tiecheng Lou
State grid shanghai cable company
No.2501, Gonghexin Road, Jingan District, Shanghai
yty@outlook.com

Abstract. In view of the challenges faced by the current HV cable O&M management, such as the growth of equipment scale, the severe security situation, the lack of comprehensive perception on equipment status, and the ability of intelligent analysis and decision-making to be improved, it was proposed to build a HV cable intelligent sensing IoT based on new sensors such as intelligent earthing box, PD intensive care unit, intelligent ground landmark and face recognition system for terminal stations, so as to comprehensively improve the quality and efficiency of HV cable O&M management. A pilot project was built in Hongqiao area in Shanghai, forming typical application scenarios such as IoT intelligent disposal, integration of monitoring and detection data in terminal stations, panoramic intelligent patrol inspection for ensuring power supply.

1. Introduction

In recent years, with the development and construction of cities, the scale of HV cables and channels have increased rapidly year by year, playing a more and more vital role in the urban power grid[1-6]. It also brings new challenges to the O&M management of HV cables and channels. First, the equipment scale is growing and the security situation is grim. Taking Shanghai as an example, the scale of cable equipment has increased by 15% annually in recent 10 years, and the workload of various operation and maintenance has increased rapidly, such as on-site inspection and detection, troubleshooting and treatment of defects. Also, the requirements for work quality are higher and higher. Second, the overall perception of equipment status is insufficient. The cable route is generally long, and all kinds of cable and channel monitoring devices are distributed discretely. There are some problems to be solved, such as insufficient perception, separate system construction, difficult information interaction. The environment in the cable well is adverse causing problems with power supply and communication between sensors. Third, the ability of intelligent analysis and decision-making need to be improved, which is mostly relied on manual judgment. The existing monitoring system mainly depends on a single dimension of monitoring data, so it is impossible to carry out comprehensive analysis and intelligent decision-making[7-9].

In this paper, it was proposed to build a HV cable intelligent sensing IoT based on new sensors such as intelligent earthing box, PD intensive care unit, intelligent ground landmark and face recognition system for terminal stations, so as to comprehensively improve the quality and efficiency of HV cable O&M management. A pilot project was built in Hongqiao area in Shanghai, forming typical application scenarios such as IoT intelligent disposal, integration of monitoring and detection data in terminal stations, panoramic intelligent patrol inspection for ensuring power supply.
2. HV cable intelligent sensing IoT

The overall architecture of HV cable intelligent sensing IoT is composed of sensing layer, network layer, platform layer and application layer\textsuperscript{[10-14]}, as shown in figure 1.

**Sensing layer**: it realizes accurate sensing of HV cables and channels by various sensors. The data is transmitted to the sink node through a short-distance low-power network for aggregation and edge computing. The sink node is compatible with different application scenarios. The collected data of channel visualization is sent to the unified video platform.

**Network layer**: it provides a channel for data transmission between sensing layer and platform layer. It mainly uses wireless private network or public network APN to realize reliable and safe data transmission.

**Platform layer**: it is composed of IoT management platform, unified video platform and middle platform. The IoT management platform is used for data access of various sensors; The unified video platform is used for data access of video image. The middle platform can access the existing system data and jointly provide data services for application layer.

**Application layer**: it is based on the data and service support from middle platform and IoT management platform. Various advanced applications and auxiliary decision-makings are realized on HV cable lean management comprehensive platform according to actual application requirements.

![Figure 1. The architecture of HV cable intelligent sensing IoT](image)

In sensing layer, HV cable intelligent sensing IoT is based on various types of new sensing terminals, including intelligent earthing box, PD intensive care unit, intelligent ground landmark, face recognition system for terminal stations, etc.

2.1. Intelligent earthing box

The intelligent earthing box adds power supply and communication unit to the original earthing box. Its power supply mode combines solar energy with battery. It also has the high-performance edge IOT agent module based on 5G communication technology. In such it solves the problem of difficult power acquisition and communication along cable ducts.

At the same time, the intelligent earthing box has integrated monitoring functions such as earthing current, partial discharge and distributed fault location. Data collected from intelligent manhole covers and intelligent ground landmarks nearby can get access to the edge IoT agent in an intelligent earthing box. In such a cable duct IoT is built with the intelligent earthing box as the carrier.
2.2. PD intensive care unit
The PD intensive care unit includes PD detection unit, energy storage unit and communication unit. It can realize remote PD on-line monitoring for 7 consecutive days and record the development trend of PD signal over a period of time. At the same time, the appearance structure fits the earthing box door, which is convenient for disassembly and assembly, as shown in Figure 3. Compared with conventional PD on-line monitoring equipment, the installation position can be flexibly adjusted.

2.3. Intelligent ground landmark
The intelligent ground landmark is also installed on cable duct like the conventional ground landmark, which plays the role of cable path identification, as shown in Figure 4. The intelligent ground landmark can sense all kinds of mechanical vibration signals near the cable duct in real time. When there is mechanical construction near the cable duct, the intelligent ground landmark shall timely push the alarm information to the cable O&M personnel, and remind the on-site construction personnel by flashing the warning light. The intelligent ground landmark can also conduct self-learning according to the on-site environment, continuously improving the alarm accuracy.

2.4. Face recognition system for terminal stations
The face recognition system for terminal stations is based on deep learning algorithm, also supporting a variety of verification methods such as face, fingerprint and card swiping, so as to realize the remote work permit and access control, as shown in Figure 5. It can automatically open and close the gate of the terminal station, effectively supervise and record the access information. In such it will save the round-trip time to the terminal station and improve the O&M efficiency. High definition video monitoring shall be installed in the working area to watch the working range and behavior of the staff intelligently, so as to prevent the staff from entering the dangerous area and misoperation.

3. Typical application scenarios
A pilot project was built in Hongqiao area in Shanghai, forming typical application scenarios such as IoT intelligent disposal, integration of monitoring and detection data in terminal stations, panoramic intelligent patrol inspection for ensuring power supply.
3.1. Intelligent disposal based on cable duct IoT
The intelligent disposal application scenario is mainly based on the sensors such intelligent ground landmark, channel visualization and intelligent earthing box. Through the communication and linkage between sensors, the emergency response and intelligent disposal based on cable duct IoT are realized, as shown in Figure 6.

![Figure 6. Intelligent disposal based on cable duct IoT](image)

In case of illegal construction on the cable duct channel, the intelligent ground landmark will immediately push the alarm signal, and the illegal construction position can be located on the control platform. The system automatically links the channel visualization device associated with the intelligent ground landmark to obtain video images, so as to facilitate the cable O&M personnel to acquire the actual situation on site and obtain evidence for illegal construction. In addition, the system provides monitoring data such as adjacent intelligent earthing box and intelligent manhole cover, so as to facilitate the cable O&M personnel to fully grasp the cable body and channel status. At the same time, the system can also directly intervene through the audible and visual alarm unit on the channel visualization device before the cable O&M personnel arrive at the site to prevent illegal construction.

3.2. The fusion of monitoring and detection data in a terminal station
The terminal station monitoring and detection data fusion application scenario mainly relies on terminal infrared temperature, terminal tail temperature and earthing current monitoring, also terminal station face recognition and other sensors. Through various intelligent sensors, routine inspection, onsite detection, access security and other work can be replaced, which makes nearly unmanned O&M of cable terminal stations. The O&M personnel can focus more on the diagnostic retest and precision test after finding the abnormal monitoring data from sensors.

![Figure 7. The fusion of monitoring and detection data in a terminal station](image)
When the infrared temperature measuring device detects that a terminal’s temperature rises, the cable O&M personnel will enter the terminal station for infrared temperature detection. Access security and operation safety control are realized through the terminal station face recognition system. After the infrared temperature measurement result is uploaded to the system, the system will automatically transfer the cable line’s load at the time of infrared temperature measurement, as well as the multi-dimensional monitoring data from sensors such as terminal tail temperature measurement and earthing current, deeply integrate the detection results with the monitoring data in the system, facilitate the comprehensive comparison and analysis, and give the causes of terminal heating and defect elimination suggestions automatically.

3.3. Panoramic intelligent patrol inspection for ensuring power supply
The panoramic intelligent patrol inspection application scenario mainly relies on various sensors and control platform. Through the automatic data drilling and panoramic presentation, the comprehensive transformation of working mode for ensuring power supply is realized.

Conventional working mode normally includes three parts. First, checking the cable line’s latest infrared, partial discharge, earthing current and other on-site detection, outage maintenance, as well as defects and hidden dangers before its power holding time. Second, arranging necessary on-site detection and defect elimination. Third, implementing line patrol or looking after during power holding time.

After registering the power holding task in the system, the system automatically drills and correlates various O&M records, defect and hidden danger accounts, so as to avoid cumbersome manual troubleshooting. The system will also provide suggestions on task arrangement of on-site detection or defect elimination. An automatic line patrol inspection function is also provided by automatically presenting the monitoring data from sensors along the cable line with the sequence of imitating manual patrol inspection, which realizes the transformation from on-road manual inspection to on-screen automatic inspection.

4. Conclusion
HV cable intelligent sensing IoT technology, which is based on various new sensors for cable bodies and duct channels, provides solutions for carrying out cable professional intelligent O&M. A pilot project was built in Hongqiao area in Shanghai, which significantly improves the O&M quality of HV cable lines and channels in the demonstration area, also saves the cost of manpower.

References
[1] Jiang Yun, Zhou Yunjie. Application of distributed partial discharge on-line monitoring technology in shanghai 500kV XLPE power cable line[J]. High Voltage Engineering, 2015,41(04):1249-1256.
[2] Zhou Yuanxiang, Zhao Jiankang, Liu Rui, et al. Key technical analysis and prospect of high voltage and extra-high voltage power cable[J]. High Voltage Engineering, 2014,40(09):2593-2612.
[3] Wang Xiaolin. Technical crux research and application of intelligent operation and maintenance
of underground cable[D]. South China University of Technology, 2016.

[4] Li Xuan. Research and application of high voltage cable operation and maintenance management based on condition detection technology[D]. North China Electric Power University, 2016.

[5] Huang Huang. Research of on line monitoring system for cable mizoi chino[D]. North China Electric Power University, 2017.

[6] Lai Liyong. Establishing the fault tree of transmission cable and its typical fault analysis[D]. South China University of Technology, 2014.

[7] Su Biaolong, Zhou Yanghao, Shi Jingyuan, et al. The simulation analysis and self checking in distribution automation running conditions and operation conditions[J]. Distribution & Utilization, 2016,33(05):70-75+56.

[8] Ai Fuchao. Research and application on integrated monitoring system of high voltage cables and cable tunnels[D]. Shandong University, 2015.

[9] Zhang Xiaolong, Xu Chunhong, Zhang Lisheng, et al. Research and application on multi-state[J]. Distribution & Utilization, 2016, 3305:70-75+56.

[10] Zhou Luyao, Cao Junping, Wang Shaohua, et al. Comprehensive state evaluation of high voltage cable based on multi-state variables characteristics and variation law[J]. High Voltage Engineering, 2019,4512:3954-3963.

[11] State grid typical design of smart IOT system application scenario(transmission volume)[M]. State Grid Corporation of China, 2020.

[12] He Jie. Research on key technologies of internet of power transmission and transformation equipments[D]. Hunan University, 2013.

[13] Wang Zhen. Research on key technologies of smart grid and internet of things[D]. Shandong University, 2017.

[14] Jing Mengchun, Wang Jiye, Cheng Zhihua, et al. Research and application of sensor information model in power internet of things[J]. Power System Technology, 2014,38(02):532-537.