The application of Internet of things technology in integrity management of urban gas pipe network

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Abstract. On the Internet of things technology in the gas pipeline integrity management the present situation of the study is less. This paper aims to improve the integrity management level of gas pipe network and combines the mature experience of Internet of things in the integrity management of long-distance pipelines. The integrity management system of urban gas pipe network based on Internet of things technology is proposed, and the main application scenarios are analyzed. The results show that the application of Internet of things technology improves the uniformity of data collection in pipe network operation management, promotes the sharing of data, and avoids multiple data conversion. The detection results of various sensing means, methods and instruments can be integrated to ensure the reliability of risk assessment and integrity assessment. To realize the scientific and reasonable allocation of limited human resources and equipment, and to evaluate the effectiveness of the existing integrity management system, to achieve the goal of gradually improving the integrity management. This paper provides specific guidance and ideas for urban gas pipe network management and operation units to carry out high level integrity management.

Keywords: internet of things, perception, urban gas pipe network, integrity management.

1. Introduction

In recent years, the pace of construction of China's city gas pipeline network has gradually accelerated, the safe operation of the pipeline network has become one of the key issues restricting its rapid development [1]-[3]. With the continuous completion of a large number of gas pipeline network and the extension of the operating time, the construction of the pipeline network in the construction, management and other aspects of the defects gradually exposed, resulting in many local gas pipeline network safety accidents [2]-[3]. City gas pipeline networks are generally located in densely populated and commercially developed urban core areas, once a safety accident occurs, the impact and loss will be huge [4]-[5]. Therefore, how to ensure the long-term safe and efficient operation of the city gas pipeline network has become a widely studied issue by scholars.

Xiao Jun's research suggests that the safety and stability of pipeline operation is directly related to the integrity management of city gas pipeline network, and in order to fully guarantee the safe and effective operation of city gas pipeline network, gas enterprises should carry out the integrity...
management of gas transmission and distribution pipelines in combination with the specific conditions of city gas pipeline network. By investigating the means of integrity management of city gas transmission and distribution pipelines in the United States, Yang Yufeng [4] and others proposed a six-step cycle of integrity management system of city gas pipeline network, including data management, leak management program. Wang Ting [2] and others believe that the integrity management of the gas pipeline network should comprehensively consider all factors affecting the integrity of the gas pipeline network, adopt an integrated management model, and establish a gas pipeline network integrity management system. The above-mentioned scholars have carried out more specific research on the city gas pipeline network, but due to the complex sources of gas pipeline network management body, management mode diversity, user structure complexity, the third party damage risk, so the current level of integrity management of the city gas pipeline network is not high [5].

At present, the outstanding problems of gas pipeline network integrity management are the low degree of informatization and the poor level of self-control [6]-[7]. Zhao Yongqi [5] and others believe that the integrity management of city gas pipeline network must be carried out based on the establishment of sound relevant norms and standards, and modern methods should be used to collect data and information, and to establish advanced information management systems to improve the integrity of the gas pipeline network. Ma Bin [7] and others believe that the Internet of Things, Big data, Cloud computing and other advanced technologies and gas pipeline network integrity management integration, is an important method and way to achieve networked gas pipeline network, informatization, visualization and intelligence.

At present, advanced technologies such as the Internet of Things have been gradually applied in the integrity management of long-distance oil and gas pipelines [8]-[14]. Dong Shaohua [10] and others believe that the application of Internet of Things technology to the design, construction, operation, maintenance and management of oil and gas pipelines will help promote pipeline failure control and integrity management and improve the safety of long-distance pipeline operation. Yang Baolong [13] and other scholars believe that the application of Internet of Things technology can solve the current problems of inaccurate data collection in pipeline integrity management, large human interference factors, and factors affecting the intrinsic safety of pipelines can not be collected in real time.

The above research shows that the application of new technologies such as the Internet of Things is one of the important ways to improve the integrity of city gas pipeline network management level, but the application of the Internet of Things in pipeline integrity management research is mainly focused on long-distance pipelines [10]-[15], there is little research on city gas pipeline network [5],[16]. Therefore, this paper analyzes Internet of Things in the integrity management of gas pipeline networks in order to provide reference for improving the integrity management of gas pipeline networks.

2. Internet of Things Technology and Integrity Management of Pipeline Network

2.1. Definition and characteristics of Internet of Things technology

The concept of the Internet of Things was first proposed by the AUTO-ID Center at the Massachusetts Institute of Technology (MIT) in the United States, and there is no clear definition yet [13]. Nowadays, it usually refers to a new network structure that connects various information sensing devices and operating devices that used to work independently through the Internet, and uses the Internet and traditional telecommunication networks as the information carriers to enable each device to operate in a unified converged state [11]. Compared to the Internet, Internet of Things can not only deliver real-time and accurate information about objects and processes; meanwhile, Internet of Things can sense and collect information and data in real time, and analyze and intelligently process the information and data obtained, so as to achieve intelligent control of objects and make them more intelligent.

The Internet of Things has three main features in terms of architecture, as shown in Figure 1: First, comprehensive perception, which can be achieved through devices such as Radio Frequency Identification (RFID), QR codes, and various types of sensors to perceive the environment and
identify information. It is like the various sensing organs all over the body, which can perceive and identify the environment and information around the human body in real time. The second is the reliable information transmission; the Internet of Things can use multiple heterogeneous networks and protocols, through wired networks, wireless communications, satellite communications technology and other transmission methods of information collected accurately and reliably transmitted, just like the nervous system in the human body, through the neural network to send the information collected by a variety of sensory organs to the brain. The third is the intelligent application processing, that is, the Internet of Things will be transmitted to the Information for intelligent induction analysis, processing and application, just like the human brain can make decisions and take actions on the received information. Based on the above characteristics, The Internet of Things has been widely used in smart city construction, industrial production and other fields, especially in the construction, safe operation and management of smart pipelines, which has huge application prospects [10]-[14].

Figure 1. Schematic diagram of the main features of Internet of Things technology.

2.2. Integrity management of city gas pipeline network

Unlike long-distance pipelines, the city gas pipeline network has many potential safety hazards in its design, construction and management due to its diverse investment and operation entities and different construction cycles. In addition, the gas pipeline network mainly serves the densely populated, commercial activities, construction of frequent, economically developed urban areas, in the event of a safety accident, it will cause serious casualties, economic losses and adverse social impact[5],[16]. Therefore, it is particularly important to carry out integrity management for the city gas pipeline network. The integrity management of city gas pipeline network is through the comprehensive collection and combing of city gas pipeline network data, and then systematically identify and evaluate the risk of pipelines, so as to prevent safety accidents and ensure the safe and reliable operation of the gas pipeline network process.
Figure 2. Flow chart of the integrity management system of the city gas pipeline network.

The core of gas pipeline network integrity management is to ensure pipeline safety and prevent the occurrence of safety accidents. For the characteristics of the gas pipeline network, combined with the long-distance pipeline integrity management process, generally speaking, the gas pipeline network integrity management process can be divided into six steps as shown in Figure 2: (1) The preparation of standardized management systems and documents, the development of scientific and reasonable technical standards and procedures for integrity management; (2) Do a good job in gas pipeline network operation and management, including routine maintenance, monitoring and inspection; (3) Use various sensors, GIS and other technologies to do network information and data collection; (4) Provide emergency response to various emergency situations in the pipeline to ensure the safe operation of the pipeline network; (5) Actively carry out the identification and risk assessment of the high-consequence area of the pipeline network; (6) Based on the pipeline network sorting out and analyzing all kinds of information and data, and formulating reasonable emergency response strategies, provide a solid foundation for the integrity management of the gas pipeline network.

2.3. Application status of Internet of Things technology in long-distance pipeline integrity management

With the gradual advancement of intelligent pipeline network construction, The Internet of Things technology has important application prospects in the integrity management of long-distance pipelines because of its unique advantages [11]. On the one hand, The Internet of Things technology can enable pipeline basic data and business data collection to achieve automatic real-time collection, avoiding the impact of previous human collection on the accuracy, integrity and timeliness of data. On the other hand, The Internet of Things technology can achieve the risk elements of pipeline intrinsic safety that could not be obtained in a timely and accurate manner by conventional means before, providing a basis for accurate pre-control.
Many foreign companies have applied the Internet of Things technology to the integrity management of long-distance pipelines [13], for example, BP in the UK uses mobile terminals to achieve on-site task assignment, work guidance, data collection, etc.; in order to improve the level of integrity management, the use of complex areas of the pipeline using drones and heat sensing technology to carefully detect and monitor. The pipeline company of Nisource of the United States uses the integrity management platform based on the Internet of Things technology, the system can use laser scanning tools to monitor pipeline leaks, the use of drones to achieve pipeline inspection and early warning, with the use of mobile terminals to carry out mobile office, data collection, display and other functions.

Many domestic long-distance pipeline companies have also carried out the integrity management work based on the Internet of Things technology. On the one hand, the established integrity management platform based on Internet of Things technology combines with the original pipeline SCADA system, and realizes the geological disaster monitoring and yin protection data collection by burying all kinds of sensors in and near the pipeline, so as to improve the integrity management level of long-distance pipelines. On the other hand, for long-distance pipeline stations and valve chambers, it uses Internet of Things technology to realize real-time input and monitoring of station asset management, equipment operating status and equipment maintenance, which improves the integrity management level of the stations yard.

2.4. Demand analysis of Internet of Things technology in the integrity management of city gas pipeline network

Based on the above analysis, it can be found that the application of Internet of Things technology can greatly improve the level of pipeline integrity management, and has been partially applied in long-distance pipelines at home and abroad [9],[13]. However, the city gas pipeline network has many differences compared to the long-distance pipeline network, first of all, the gas pipeline network has many pressure levels, the pipeline materials and specifications are diverse, and the most of the network distribution; secondly, most of the gas pipeline network with urban construction and gradual laying, so the gas pipeline network in a complex environment, high population density, high consequence area dense and security risks; in addition, the gas pipeline network is more disturbed by factors, such as internal pressure and combined vehicle loads, stray current interference and third-party damage are more frequent.

The characteristics of the city gas pipeline network shows that the integrity management system of the gas pipeline network and the integrity management of the long-distance pipeline is not identical. It is necessary to establish an integrity management system based on the characteristics of the gas pipeline network. From the analysis of the characteristics of the gas pipeline network can be seen that the safety of the gas pipeline network by more interfering factors, the safety risk of the pipeline network is greater, the traditional integrity of the management system and means have been unable to meet the current requirements of the integrity of the gas pipeline network management. Therefore, based on the application of Internet of Things in long-distance pipeline network, it is necessary to develop an integrity management system based on Internet of Things technology for the unique characteristics of gas pipeline network.

3. City Gas Pipeline Network Integrity Management System Based on Internet of Things Technology

To service the business needs of the gas pipeline network as the dominant, improve the integrity of the gas pipeline network management level for the purpose, combined with domestic and foreign has been applied in the long-distance pipeline integrity management on the basis of the Internet of Things technology, proposed a city gas pipeline network integrity management system based on Internet of Things technology is shown in Figure 3.

The new model of city gas pipeline network integrity management system based on Internet of Things technology can be divided into 4 layers as shown in Figure 3, which are perception layer,
network layer, data layer and application layer. The system can connect assets and equipment through various sensing means such as sensors, improve the digitalization of the gas pipeline network, realize the collection and transmission of basic pipeline information, establish an integration system of information, and realize the comprehensive analysis and utilization of information. Ultimately, at the level of business applications, it can realize the daily operation and management of the pipeline network, the identification and evaluation of high consequence areas, and the function of integrity evaluation, and at the level of decision analysis, it can realize the function of integrity management and audit, intelligent control of the pipeline network, the evaluation of the performance of the pipeline network, and the formulation of emergency strategies and plans. Through the integrated application of the gas pipeline network integrity management system based on the Internet of Things technology as shown in 3, it can effectively solve the problems of timeliness, accuracy and integrity collection and transmission of information and data in the gas pipeline network integrity management at this stage, and can meet the needs of different management levels in the gas company at this stage.

Figure 3. Application architecture diagram of gas pipeline network integrity management based on Internet of Things technology.

4. Application scenarios of city gas pipeline network integrity management system based on Internet of Things technology

4.1. Data collection and standardization
In the integrity management of the gas pipeline network, the collection and integration of information and data is a fundamental and important task. The information and data required for integrity management should include different stages and types of the whole life cycle of the gas pipeline
network, and pay attention to the collection at the source. A unified data information platform can be established based on Internet of Things technology to unify the management of data from the perception layer and integrate the dispersed data. At the same time, in the specific operation, it is necessary to improve the development of data standards, especially the pipe segment coding, pipe segment coding attributes and other information, and gradually form a system of standard data, so as to improve the unity of data, promote data sharing in integrity management, and avoid multiple conversions and repeated entry of data. For example, using the GIS system based on the Internet of Things technology to collect pipeline attributes and environmental data, and establishing a project site data acquisition system to collect important process and event records, construction records and evaluation reports during the construction process. In the daily management of pipelines, a safe operation management system based on the Internet of Things can be used to collect business information such as maintenance, inspection, operation and failure of gas equipment. Gas managers can also collect information and data on daily pipeline operation, illegal occupation of pressure, and third-party engineering construction into the pipeline inspection system based on the Internet of Things technology. Based on the Internet of Things technology, accurate and timely information and data collection, laying a solid foundation for the development of gas pipeline network integrity management.

4.2. Risk identification and evaluation
Risk identification and evaluation of pipelines is one of the important steps in gas pipeline network integrity management, mainly refers to the identification of factors affecting the safe operation of the gas pipeline network based on the basic information and data collection of pipelines, evaluating the possibility and consequences of accidents, obtaining the safety risk size comprehensively, and proposing corresponding emergency strategies and plans. In the risk identification and evaluation of city gas pipeline network based on Internet of Thing technology, the identification and evaluation of risk factors can be carried out as the steps shown in Figure 4. Firstly, the identification of risk factors for the pipeline network can be carried out by using a standardized fault tree method to identify the risk factors of gas transmission and distribution pipelines. After the identification of risk factors affecting the safe operation of the gas pipeline network, further calculations and analysis of the failure probability and safety risks are carried out to obtain the results of the safety risk evaluation and feedback to the level of decision analysis. Generally, an intuitive semi-quantitative method can be used for evaluation, based on the various types of risks perceived by the Internet of Things, for risk evaluation, and direct application of risk evaluation models or business risk evaluation software integrated with Internet of Thing technology.
Determine the purpose and scope of pipeline network risk identification and evaluation

Hazard identification

Standardized accident fault tree

Failure probability analysis

Security risk calculation

Security risk assessment and feedback

Figure 4. Risk assessment diagram of gas pipeline network integrity management.

4.3. Completeness evaluation
The integrity of the city gas pipeline network may be damaged by intrinsic factors such as defective issues in the pipeline construction process, external factors such as damage and corrosion, thus reducing the service life and safety of the pipeline, so it is necessary to carry out integrity evaluation in a timely manner. City gas pipeline network integrity evaluation based on Internet of Thing technology is to obtain pipeline defect information through all-round, real-time sensory detection technology, so as to evaluate the integrity of the gas pipeline network, which can determine the safe operation status of the pipeline in the current and future period of time. The safe operating state of the perceptual detection technology based on the Internet of Things can enable the detection of pipe defects, anti-corrosion layers, soil parameters, stray current interference, and so on. The previous detection methods may be due to the intersection of city gas transmission and distribution pipelines and other municipal facilities, there are more interference sources, and the accuracy of the detection results is not high due to the limitations of the detection methods or the corresponding instruments. The city gas pipeline network integrity evaluation based on the Internet of Things technology can be integrated with a variety of methods and instrumentation of the test results, thus ensuring that reliable results can be obtained. Following this can be more accurate assessment of the remaining life of the pipeline and residual strength, to predict the development trend of pipeline integrity damage, the development of targeted maintenance and repair plans.
4.4. Pipeline network maintenance
After the above risk assessment and integrity evaluation of the gas pipeline network, the defects and risk points of the pipeline network can be effectively identified. Thus, a reasonable program of pipeline patrol, defect repair and corrosion risk control can be formulated based on the results of the above evaluation. Effective work order management can be achieved through the development of a reasonable arrangement of maintenance plans, and the whole process of maintenance and repair in real time in the gas pipeline network integrity management platform based on the Internet of Things. Through effective work order follow-up maintenance plans and measures, it can effectively eliminate safety risks, while achieving a reasonable allocation of limited human resources and equipment, and solve the shortcomings of the traditional maintenance management information response is not timely, more human factors, can not be visualized, low management efficiency.

4.5. Effectiveness evaluation
The effectiveness evaluation of gas transmission and distribution pipeline integrity management is one of the important measures to ensure whether the integrity management system is reasonable and scientific. The gas pipeline network integrity management system based on the Internet of Things technology can make use of its own perfect and comprehensive information and data statistics, integration, storage, analysis functions, and regularly carry out performance evaluation of the existing pipeline integrity management, and the operation, management and maintenance history of the pipeline network to form an electronic, information-based records, to facilitate year-by-year comparison. Gas enterprises can apply the Internet of Things technology to conveniently evaluate the effectiveness of the existing integrity management system, and according to the corresponding results, gradually improve and perfect the integrity management methods and improve the management level.

5. Concluding remarks
Through the analysis of the characteristics of the Internet of Things technology, combined with its application in the integrity management of long-distance pipelines, a city gas pipeline network integrity management system based on Internet of Things technology is proposed for the characteristics of the city gas pipeline network, and the main application scenarios are analyzed. It provides specific guidance and ideas for city gas pipeline network management and operation units to carry out high level integrity management. Applying Internet of Things technology to urban pipeline integrity management has the following advantages.

(1) The application of Internet of Things technology can provide accurate and timely information and data collection, improve the uniformity of data collection, promote data sharing, avoid multiple conversions and duplicate data entry, and lay a solid foundation for the development of gas pipeline network integrity management.

(2) The risk evaluation and integrity evaluation of city gas pipeline network based on Internet of Things technology can realize the integrated use of multiple sensing means, multiple methods and instrumentation to ensure that reliable results can be obtained.

(3) Based on the application of Internet of Things technology, you can reasonably allocate limited human resources and equipment, and can conduct performance evaluation of the existing integrity management system, so that you can gradually improve and perfect the integrity management methods, improve the integrity of the city gas pipeline network management level.

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