Design and research of Sense, Know, Anticipate and Protect Integrated Intelligent Gas Pipeline Network Security System

Shuai Zhang[1,a], Chen Li[1,b,*], Jiale Ren[1,c], Haoyu Lan[1,d], Chiyu Wang[1,e], Zixin Wu[1,f], Yuanfang Chen[1,g]

[1]School of Architecture and Design, Beijing Jiaotong University, Beijing, China.

[a]shuaizhang@bjtu.edu.cn, [b]21126388@bjtu.edu.cn, [c]22126447@bjtu.edu.cn, [d]22126475@bjtu.edu.cn, [e]21126397@bjtu.edu.cn, [f]21126436@bjtu.edu.cn, [g]21126382@bjtu.edu.cn

[*]Corresponding author

Abstract. Nowadays, China's gas pipeline network accidents are frequent, and gas accidents cause significant losses to people's lives and property safety, exposing many loopholes and shortcomings in urban safety management. Traditional social warning methods for gas safety accidents are insufficient and information dissemination is not in place, making it difficult for people in gas risk areas to obtain effective and timely warning information, often resulting in major gas explosion casualties. Home gas leaks are often more difficult to detect and dispose of, and coupled with the weak awareness of gas safety among users and their reluctance to purchase corresponding gas leak alarm devices, the safety problems faced by home gas are very serious. The paper focuses on gas safety hotspots, dovetails with national urban safety development strategies, and proposes 3 sets of system solutions through system innovation, technological innovation, and financial innovation for key and difficult issues such as gas safety monitoring, social surface warning, and user protection system construction. At the government management level, it realizes real-time and precise monitoring of gas pipeline networks. At the social early warning level, it realizes real-time systematic delivery of risk information. At the household protection level, it realizes household gas safety monitoring and the construction of a protection system. The 3 sets of solutions are hierarchical and logically progressive, forming a closed-loop working system of gas safety monitoring, early warning, management and guarantee for the whole field of government, society and family, providing a new system thinking, technology integration and operation system for the field of city gas safety.

Keywords: Emergency management; Gas safety; Gas pipeline network monitoring; Gas risk warning; Gas safety assurance.

1. Introduction

Security is the cornerstone of the development of the Party and the State all undertakings. With China's urbanization process accelerated significantly, urban population, function and scale of the expanding, development, industrial structure and regional layout has undergone profound changes, new materials, new energy, new technologies are widely used, new industries, new business models, new fields emerge, urban operation system is increasingly complex, increasing security risks. Some cities with a weak safety foundation, safety management level and modern urban development requirements do not adapt, uncoordinated problems are more prominent. In recent years, some cities and even large cities have experienced serious production safety accidents, especially in the field of gas safety. According to the National Gas Accident Analysis Report issued by the Safety Management Committee of the China City Gas Association, in the first half of 2022, there were 271 accidents among residential users, 63 accidents among industrial and commercial users, 117 accidents in the pipeline network, and 6 accidents in plant stations[1]. Nowadays, gas pipeline network accidents are frequent in China, and gas accidents cause significant losses to people's life and property safety, which expose many loopholes and shortcomings in urban safety management.

In 2018, the Opinions on Promoting Urban Safety Development issued by the General Office of the CPC Central Committee and the General Office of the State Council put forward 3 strategic

requirements for urban development, including strengthening urban safety source management, improving urban safety prevention and control mechanisms, and enhancing urban safety supervision effectiveness[2]. In 2021, the State Council Security Committee Office's "On Promoting the Experience and Practice of Urban Lifeline Safety Projects to Effectively Strengthen Urban Safety Notice on Risk Prevention" further pointed out that priority should be given to improving gas warning and disposal functions, making full use of scientific and technological means, accelerating the establishment of a sound comprehensive monitoring and warning work system for city gas, and improving the level of gas system safety risk identification, prevention, and resolution.

The people's hope for urban safety and the Party and State's requirements for city gas safety work have raised new issues for us in our times. The safety status of China's city gas pipeline network mainly has the following characteristics: (1) easy to leak: the gas pipeline network itself has many weak links, and is greatly affected by the quality of pipeline construction and the surrounding environment, and previously usually uses gray cast iron pipes and backward pipe connection methods and anti-corrosion measures, making the pipeline into the accident-prone period; (2) difficult to detect: gas pipeline leak detection methods mainly rely on manual inspection, the inspection time detection area Both have limitations, in addition to the pipeline tiny leaks are difficult to detect and find; (3) dangerous: gas permeates through underground voids and gathers in the underground confined space, which can easily lead to poisoning, fires or large-scale explosions; (4) difficult to dispose of: gas companies usually use excavation to find leaks in the process of accident disposal, resulting in low efficiency of accident rescue and improper excavation operations that can easily cause explosions.

At present, the equipment, installation, monitoring, and operation of the city gas pipeline network have several urgent problems that need to be solved due to historical legacy. Firstly, in the field of gas pipeline network hidden danger accurate detection, gas pipeline buried in the ground, sensor detection function is concentrated in the gas well, encounter warning, need further manual judgment, belong to the "half intelligent half artificial" system process, can not achieve rapid, accurate positioning hidden danger orientation. Second, in the field of the social evacuation of gas hazards, the closed safety system of "hazards occurrence-warning issuance-crowd evacuation-hazards lifting-feedback follow-up" has not yet been formed a management system. Once again, in the field of customer gas security system construction, it is still in the state of individual security of equipment warning, maintenance, and customer worry, and no chain security system has been constructed.

Based on the above background, the article proposes an integrated intelligent gas network security system of "Sense, Know, Precaution and Protection" to provide an innovative intelligent solution to the above problems.

2. Literature Review

2.1 Technical methods for monitoring gas pipeline networks

In 2020, engineer Wen Dingkun proposed that multiple monitoring and protection measures should be explored to guarantee information security in order to provide information support to ensure production safety and maintain stable operation of the system, in view of the characteristics that the gas pipeline network control system can monitor the status of all equipment and devices in the production system in real time[3]. Bin Chen proposed a real-time information collection and analysis system integrating cathodic protection, digital communication, telemetry monitoring, and Internet technologies for the current gas pipeline network cathodic protection potential detection, which generally adopts manual detection, resulting in inconvenient operation, large measurement errors, and discontinuous data, to facilitate the realization of real-time monitoring of the operating conditions of gas pipeline network cathodic protection system in some special areas by gas companies and the data[4]. In 2021, Feng Ji and other scholars conducted a series of functional analyses of gas pipeline network monitoring equipment and technologies in order to objectively

analyze and assess the feasibility from various aspects such as technology, economy, and use, and concluded that no single technology can completely solve all the problems of safety protection along the pipeline, so the research and application of more new methods and new technological means will be the city gas pipeline network monitoring Early warning technology is a constant pursuit[5].

In 2021, Khan et al. used digital signal processing technology to analyze the vibration response characteristics of gas pipelines to monitor potential defects in dynamic systems. In 2022, Wang et al. developed a mathematical framework to analyze the reliability of pipeline networks, based on fault analysis of key network components and providing insights into pipeline network security[6]. So far, some foreign companies, such as Ferroscope 308 type detector based on far-field eddy current technology developed by Canada's Russell Technology Ltd, WAVE: MAKER G3 monitoring system by UK Ultrasonic Wave Guide Ltd, Teletest long-distance pipeline ultrasonic wave guide monitoring system by UK PI, Southwest Research Institute developed by US MsSR3O3O type magnetostrictive monitoring system, etc., have been widely used in the safety monitoring of gas pipeline system.

Domestic and foreign gas pipeline monitoring technology methods are mainly: (1) fiber optic leak detection method: leak point pipeline emits acoustic signals, acting on the point fiber optic cable, acoustic waves acting on the fiber optic cable caused by optical signal modulation, through demodulation signal processing to obtain acoustic signals, by pattern recognition algorithm to determine the characteristics of the leak point, through the light pulse to locate the leak point location; (2) negative pressure method: the negative pressure wave leak detection principle is that, after a leak occurs in the pipeline, the negative pressure wave generated at the leak point will propagate in the form of fluctuations upstream and downstream of the pipeline, using the pressure transmitter installed upstream and downstream of the pipeline can detect the negative pressure wave signal, so as to determine whether the pipeline is leaking; (3) infrasound method: leak detection and location by detecting the infrasound generated by the turbulent jet of the leaking fluid acting on the pipe wall. Analysis of low-frequency acoustic signals detected when the pipeline leaks; (4) radar method: the use of electromagnetic principles to detect underground pipelines, through the emission of electromagnetic crack reverse acquisition to locate the pipeline leak point, suitable for large diameter or non-metallic pipeline detection.

2.2 Technical methods for gas event warning

The term "early warning" was first applied in the military field, but later it was gradually applied in many research disciplines such as economics, sociology and natural science. The first French economist Alffed fourille applied early warning theory to the field of economics, and since then the early warning theory system has been continuously improved and developed in various fields such as coal, fire fighting, electricity, agriculture and health care. Domestic and foreign research on gas events mainly includes pipeline preplanning system generation, risk evaluation, reliability and program evaluation.

In 2022, Li Sijie and Wang Yahui et al. processed and extracted information for gas emergency safety incidents based on Knowledge Graph (KG) technology for emergency response, and proposed a graph construction method for emergency response of gas emergencies[7]. Dong Yinxing and Wang Huaixiu of Beijing University of Architecture proposed a gas emergency emergency decision-making method based on case reasoning technology, which collects various types of gas accident cases for information analysis and processing, and is used for emergency-assisted decision-making in gas emergencies[8]. Niu Miaomiao of Xi'an University of Architecture and Technology studied and analyzed the unconventional emergencies of city gas pipelines, and combined the "scenario-response" theory, cloud prospect theory, and regret theory to build a more complete emergency plan and decision model[9]. Based on the Bow-Tie model, Cui Jinyu and Zhan Shuhui quantified the causes, consequences, and importance of the paths of corrosion and leakage of gas pipelines, and concluded the best interception measures for the paths

of corrosion, corrosion, and leakage of gas pipelines[10]. Foreign scholars mainly focus on the prediction stage of emergency management, reliability life detection, and risk decision evaluation. Qasem Davarikhah, D. Jafari et al. used an adaptive neuro-fuzzy inference system (ANFIS) for early warning of separators in oil well pipelines, and parameters such as valve opening rate, gas flow rate, pressure value, and temperature were input into the model to complete the analysis of separator explosion. E Zarei uses dynamic risk analysis (DRA) to dynamically restore and model the accident site and uses robust tools to analyze the risk environment and develop emergency response strategies and measures that match the accident scenario[11]. Markus Brachner proposes multi-objective conditional optimization and constraints based on response time and response initiatives of performance metrics for emergency decision-making objectives.

2.3 Technical methods for the safety and security of the household gas pipeline network

At present, domestic and international security for gas pipeline networks is mainly focused on external interventions suffered during the operation of transport pipelines, such as human damage, ground construction, natural disasters and improper household use. The total control system monitors the signal identification and status of the entire pipeline through a remote real-time monitoring system, so as to alert and locate where damage to the pipeline has occurred, prevent external damage in a timely manner and make corresponding emergency measures. In recent years, with the development of control technology, information processing, machine learning and other technologies, these technologies have shown unique advantages in home gas pipeline network security technology and methods.

In 2023, Zhang Qiang, Kang Yi et al. designed an IoT and AI "gas & dry burn" safety monitoring system based on IoT technology to effectively prevent home gas safety accidents through intelligent monitoring and remote warning systems[12]. 2022, Wang Zhuanqing, Liu Kun et al. established an evolutionary game model between gas companies and government regulators based on the In 2022, Wang, Zunqing, Liu, and Kun established an evolutionary game model of gas enterprises and government regulators, and studied the evolutionary process of strategy selection of the two game subjects based on evolutionary game theory, and compared and analyzed the evolutionary stable equilibrium of the behavioral strategies of gas enterprises and government regulators[13]. Huang et al. used combustible gas and temperature sensors to collect data in town cellar wells in real time, and designed alarm thresholds to realize the leakage alarm of combustible gas[14]. Jialu Feng from Shanghai University of Applied Technology designed and completed a home gas alarm safety device based on STM32 microprocessor and evaluated its device in conjunction with safety engineering to provide a solution reference for solving the leakage of gas in households[15]. Hou et al. proposed a method to optimize pipeline leakage monitoring points, which monitored the leakage diffusion radius and effective length, and achieved a reduced monitoring point in monitoring of gas pipeline leaks[16]. Wang et al. designed a natural gas online monitoring system that enables online monitoring of natural gas leaks and online calibration of raw data through neural networks[17]. Karumanchi Meeravali et al. in 2022 required the inclusion of flame out in twelve safety protection measures for German wall-hung protection function and ionizing flame control device, which cuts off the gas supply and lights up to indicate when the flame is extinguished, prevents residual and incomplete combustion, and accesses a manual recovery function for gas safety[18].

2.4 Review of research status

One of the shortcomings of existing research: at the government management level, the above methods focus on monitoring without control means and are susceptible to interference and misreporting, making it difficult to control the accident site in a timely manner. Even if the situation is detected, it is difficult for pipeline maintenance personnel to reach the scene in the first place. In addition, managers are not able to detect and identify hidden dangers and assess risks in a timely manner and direct the disposal in a scientific manner. Therefore, with the frequent occurrence of

pipeline accidents, the invention of a visualized intelligent pipeline network system with a series of manipulation means such as timely grasping the operation status of various types of pipelines, accurately locating the accident location, and controlling the accident pipeline in real time is already an inevitable need for urban development.

Existing research deficiency No. 2: At the level of social warning, the traditional gas leak warning method in the city pipeline network after the discovery of gas leaks, sensor alerts, to police lights to remind, further monitoring system may use the background software warning, cell phone APP way to notify management personnel, ignoring the people in the gas risk area, often resulting in major gas explosion casualties. Therefore, it is particularly important to research and develop a series of gas leak social warning safety systems such as timely grasp of the location of people associated with risk areas, systematic delivery of warning information, and safe evacuation of people at risk.

The third shortcoming of existing research: At the household level, it is easy to find through the current situation that household gas leaks are often more difficult to detect and dispose of, and coupled with the weak awareness of gas safety among users and their reluctance to purchase corresponding gas leak alarm devices, the safety problems faced by household gas are very serious. Therefore, the construction of a set of timely detection of home gas leaks, real-time control of gas conditions, accident safety and security integration of the security system needs to be explored.

3. Research Content and Significance

Focusing on hot issues of gas safety, the paper dovetails with national urban safety development strategies and proposes three sets of system solutions through system innovation, technological innovation, and financial innovation for key and difficult issues such as gas safety monitoring, social level early warning, and user protection system construction. At the government management level, it realizes real-time and precise monitoring of gas pipeline networks; at the social early warning level, it realizes real-time systematic delivery of risk information; at the household protection level, it realizes household gas safety monitoring and the construction of a protection system. The three sets of solutions are hierarchical and logically progressive, forming a closed-loop system of gas safety monitoring, early warning, management and security for government, society and households, providing new system thinking, technology integration and operational systems for the field of city gas safety.

4. Overall Architecture Design of Intelligent Gas Pipeline Network Security System

4.1 Overall idea of the plan

The program focuses on gas safety hot topics and proposes corresponding solutions for existing problems in the industry: accurate monitoring and visualization management of city gas pipeline network, social warning and evacuation, and home gas security: gas pipeline network visualization monitoring system based on IOT perception technology, gas risk warning and evacuation system based on dual base station continuous tracking, and home gas security system based on service design theory. system based on service design theory. The specific ideas are as follows:

(1) Realize real-time and accurate monitoring of gas pipeline networks at the government management level.

Focusing on the monitoring and control of the city gas pipeline network at the government level, based on data collection and cloud computing processing technology, through IOT risk perception, data platform construction, data research and analysis, forming data management visualization, leakage analysis visualization, early warning control visualization; building a gas safety management system with dynamic safety supervision, normalized hidden danger investigation, and scientific special response.

(2) At the social warning level, the risk information is delivered in a real-time system.

Focus on the social level gas leak warning evacuation problem, based on the use of dual base station wireless sensor network technology, the design of gas risk warning evacuation system, through dual base station network construction, early warning analysis and evacuation information dissemination, accurate positioning of people near the risk point and send alarm information, to achieve a comprehensive coverage of social level warning information, effective evacuation of accidents, to avoid the loss of people's lives and safety to the maximum extent.

(3) At the household level, we form a household gas safety monitoring and security system.

Focus on the family level gas security protection issues, the introduction of service design concept, for the installation of home gas alarms, the use of "experiential" promotion and installation, so that the product quickly covers the user range, after the user experiences the practicality of the product to further provide monitoring, early warning, data sharing and other customized security services, through the home gas leak safety Through the coupling of home gas leak safety monitoring and insurance safety services, we can achieve the timely treatment of home gas leaks and the synergistic construction of a risk safety protection system. The general idea of the project is shown in Figure 1.

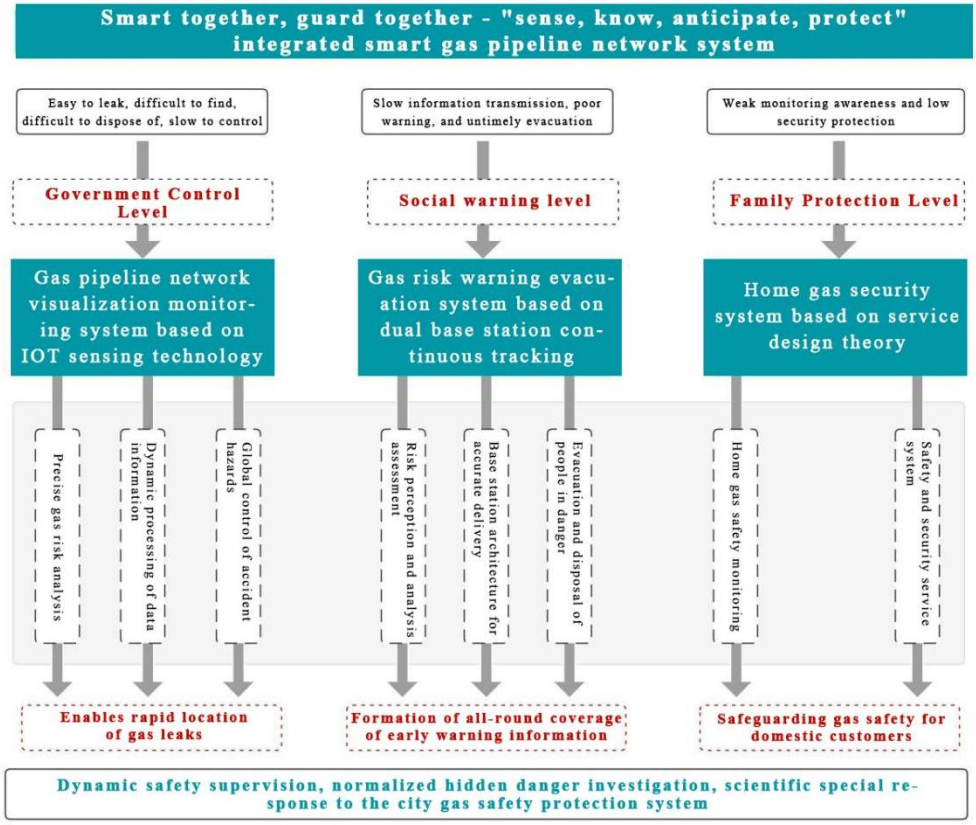

Fig. 1 Overall project concept

4.2 Implementation Feasibility Analysis

The construction of the technical system of the program includes Program I: gas pipeline network visualization monitoring system based on IOT perception technology, Program II: gas risk warning evacuation system based on continuous tracking of dual base stations, and Program III: home gas security system based on service design theory.

Program I solves the problem of real-time and accurate monitoring of city gas pipeline networks, realizing the effects of data management visualization, leakage analysis visualization, and early warning control visualization, and building a data foundation and application system platform for Program II; Program II solves the problem of social early warning evacuation of gas leaks, realizing the effects of all-round coverage of social early warning information and effective evacuation of

personnel. Solution 3 solves the problem of home gas security, realizing the effect of timely handling of gas leaks and the construction of a risk security system. The three groups of technical solutions are progressive and logical, with technical support, forming a complete closed-loop logic.

4.3 Technical Feasibility Analysis

Scheme I Gas pipeline network visualization monitoring system based on IOT perception technology: perception equipment laying involves sensor technology, IOT perception technology; IOT NB-loT technology is used to transmit perception signals and data collection of gas pipeline network basic information, monitoring information, event information, geographic information, early warning information, etc. is gathered to the data platform. Data platform construction involves BIM+GIS technology and cloud computing technology; relying on BIM software Revit 3D modeling, carrying GIS GIS platform to build 3D information model of city gas pipeline network, and processing various sensing data with the help of cloud computing technology. Management system construction involves data analysis and processing related technologies, and various technologies have mature application experience in different fields. The project team is developed by experts in different fields to jointly analyze technical features and system operations to ensure the technical feasibility of the program.

Program II Gas risk warning evacuation system based on dual base station continuous tracking: dual base station architecture design wireless sensor network technology, early warning analysis involves data analysis and processing technology, evacuation information release involves GPS positioning technology, each key technology has been applied in different fields, the team will also carry out model parameter optimization and data validation to further ensure the system operation feasible.

Program 3: Home gas security system based on service design theory: This program unites insurance companies to provide security services, charging users a monthly residential service fee and giving away home gas alarms. The system integrates the application of modern information technologies such as fiber optic sensing, Internet of Things, cloud computing, mobile Internet, and BIM/GIS to thoroughly sense the operating conditions of the home gas network.

Home gas safety monitoring involves sensor technology, IOT sensing technology, using MQ-2 gas-sensitive sensors for combustible gas monitoring; data collection and transmission with the help of ZigBee technology; various technologies have mature application experience in related fields to ensure the technical feasibility of the program.

5. Gas Pipeline Network Visualization Monitoring System Based on IOT Sensing Technology

5.1 Overview of scheme design

The program focuses on the monitoring and control of the urban gas pipeline network at the government level. Based on data collection and cloud computing processing technology, data management visualization, leakage analysis visualization and early warning management and control visualization are formed through IoT risk perception, data platform construction and data judgment analysis; Build a gas safety management system with dynamic safety supervision, normalized hidden danger investigation and scientific special response.

5.2 Methods and technical paths

The method and technical route are shown in Figure 2.

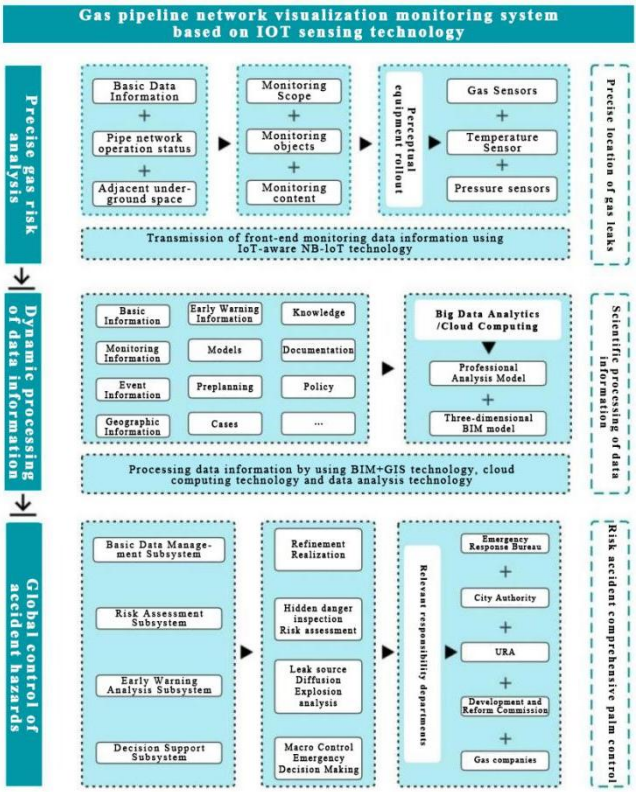

Fig. 2 Technical route

5.3 Implementation plan

5.3.1 Precision dialysis Natural gas risk

For the laying of sensing equipment in urban underground gas pipeline networks, there are three main objects, as shown in Figure 3.

Firstly, it is the internal space of the gas well; Monitoring the change of internal gas concentration and temperature by setting combustible gas sensor and temperature sensor; In addition, the valve electromagnetic control valve is set to monitor the abnormal condition of the valve;

Secondly, it is the gas pipeline wall; By setting combustible gas sensor and electromagnetic pressure sensor. It can realize the rapid and accurate location of gas leakage, and solve the problem of procrastination in deriving gas leakage points in traditional gas wells.

Thirdly, check wells (sewage wells, power wells, communication wells, etc.) for various pipelines intersecting or adjacent to gas pipelines; By setting combustible gas sensors and temperature sensors, the problem of explosion risk caused by gas leakage to adjacent underground spaces is solved.

The above monitoring sensors are deployed independently, and the equipment adopts gateway integrated design, which can directly convert the collected data signals into TCP/IP protocol and transmit them to the data platform through the network by using IoT sensing NB-loT.

5.3.2 Dynamic processing of data information

Relying on big data processing and cloud computing technology, the big data platform is constructed to analyze and process the acquired data, as shown in Figure 4. The content includes three aspects of gas pipeline network basic information processing, three-dimensional BIM modeling and professional analysis model establishment to realize standardized data processing, three-dimensional display and special algorithm model construction of gas pipeline network basic information, adjacent underground space, historical maintenance records, sensors and other information.

5.3.3 Global control of accident hazards

The back-end monitoring management system is built to comprehensively grasp the safety status of the gas pipeline network and control the accident potential hazards in a global manner. The monitoring management system serves the relevant government departments and is based on a data platform to process the content for visualization. The system is divided into five major subsystems, and the system interface is shown in Figure 5.

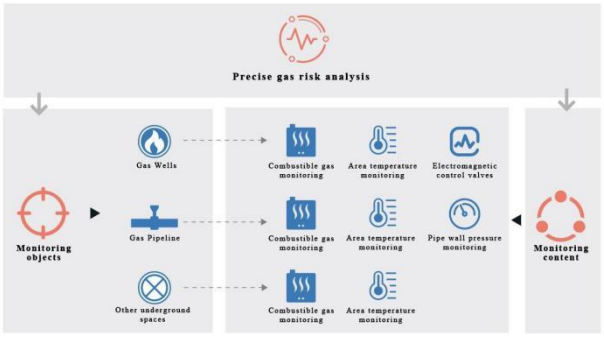

Fig. 3 Schematic diagram of laying sensing equipment

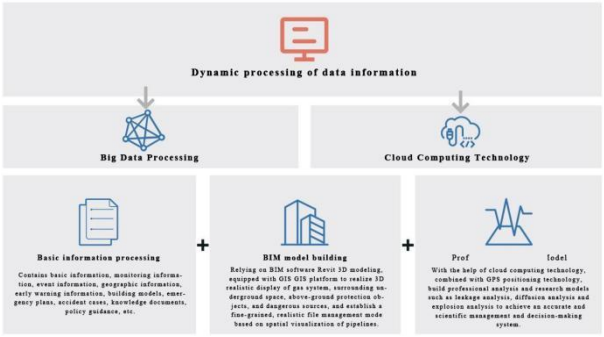

Fig. 4 Schematic diagram of data processing flow

Fig. 5 Application system interface

Fig. 6 Realistic visualization of gas pipeline network

Fig. 7 Risk assessment of gas pipeline network Heat

Fig. 8 Leak traceability analysis, leak dispersion analysis, and explosion warning analysis

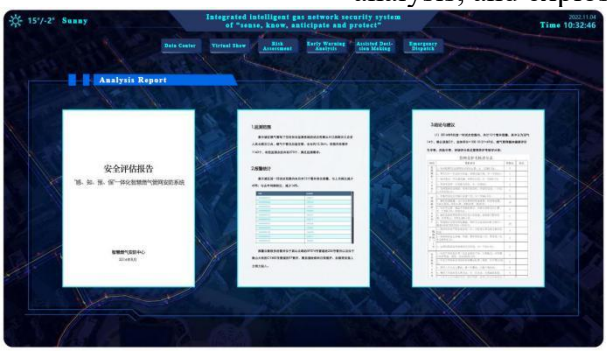

Fig. 9 Decision Analysis Report

1）Basic data display subsystem

Combined with GIS system and BIM model, it realizes 3D realistic display of gas system (pipeline network, field station, valve chamber, etc.), surrounding underground space, above-ground protection objects and dangerous sources, and establishes a refined and realistic file management mode of pipelines based on spatial visualization, as shown in Figure 6.

2）Risk assessment subsystem

The main functions of the risk assessment subsystem include risk assessment management, risk assessment heat map, and illegal occupation query, as shown in Figure 7. The system regularly assesses the safe operation status of gas pipelines, improves the refined management of the gas system based on the assessment results, and promotes the transformation of the gas system to an early warning and diagnostic safe operation mode.

3) Early warning analysis subsystem

The early warning analysis sub-system can realize leak traceability analysis, combustible gas diffusion analysis and explosion early warning analysis, as shown in Figure 8. After receiving the abnormal alarm information of the pipeline network, it identifies the source of leaking gas according to the leakage characteristic curve, applies the big data analysis method, and quickly locates the leaking pipe section based on the prompt of the sensing IOT equipment. When a gas leak occurs, the valve is remotely closed at the first time to avoid further gas leaks that can lead to larger safety accidents.

4）Auxiliary decision-making sub-system

The auxiliary decision-making subsystem regularly conducts statistical analysis of information related to pipeline risks, operation alarms, repair and maintenance, and disposal of emergencies, and distributes the analysis reports to relevant functional management departments and government leaders to give them a macro control of the safety status of the gas pipeline network, as shown in Figure 9.

5.4 Solution summary

The program focuses on the problem of gas pipeline network safety monitoring and control at the government level, and forms a visualized intelligent monitoring system based on IOT perception, BIM+GIS and other technologies through the method of accurate monitoring by perception equipment. The system is based on three steps: laying of IOT sensing devices, data platform construction, and management system construction, forming data management visualization, leakage analysis visualization, and early warning control visualization; realizing one-stop processing and linkage command of gas leakage accident response.

The research and development of this system provides the relevant government departments with visualized intelligent monitoring applications, realizing timely perception of gas pipeline system risks, early prediction and early warning, and efficient disposal and response. It also provides a data base and management platform to support the next step of early warning and evacuation at the social level.

6. Gas Risk Warning Evacuation System Based on Dual Base Station Continuous Tracking

6.1 Solution design overview

The program focuses on the social level gas leakage early warning evacuation problem, based on the use of dual base station wireless sensor network technology, the design of gas risk early warning evacuation system, through dual base station network construction, early warning analysis and evacuation information dissemination, accurate positioning of people near the risk point and send alarm information, to achieve a comprehensive coverage of early warning information at the social

level, effective evacuation in the event of an accident, to avoid the maximum extent of people's lives and safety loss.

6.2 Methodology and technical route

The method and technical route are shown in Figure 10.

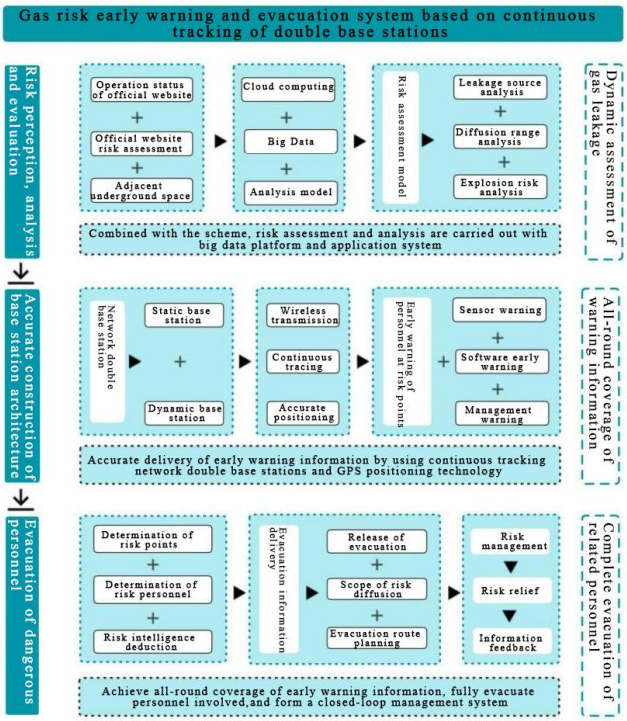

Fig. 10 Technology Roadmap

6.3 Implementation plan

6.3.1 Risk perception and analysis and assessment

The program is based on real-time monitoring data of the pipeline network and adjacent underground space for risk perception assessment, relying on the data platform and risk assessment subsystem built in Program I to construct a professional analysis model; when a gas leak occurs, leak traceability analysis, combustible gas diffusion analysis, and explosion warning analysis are conducted.

6.3.2 Base station architecture for accurate delivery

The gas risk warning evacuation system focuses on the effectiveness of wireless sensor network transmission. The system sets sensor warning, software warning, and management personnel cell phone APP warning based on the addition of crowd warning around the risk point of leakage. The system uses a dual-base station wireless sensor network architecture to send hazard warnings to people within the risk area. The network architecture contains two base stations: one is a static base station, deployed in the center of the monitoring area, as a reference base station; the other is a dynamic base station, the algorithm can further precise the range of continuous objects and minimize the number of participating nodes to locate mobile personnel signals[19], as shown in Figure 11.

Fig. 11 Schematic diagram of wireless sensing dual base station network positioning

Fig. 12 Early warning evacuation information dissemination and risk location map

6.3.3 Evacuation of personnel involved in risk disposal

After the early warning analysis and research, GPS positioning technology is combined to determine the risk points, personnel involved in the risk and carry out intelligent rehearsal of risk incidents; evacuation information is sent to the personnel involved in the risk points through the network base station with the risk point map, and risk release information is sent after the risk is handled. To achieve all-round coverage of early warning information, forming a closed-loop management system, as shown in Figure 12.

6.4 Solution summary

Through the architecture of dual base station wireless sensor network, combined with the data management system of dynamic risk assessment, through continuous tracking of gas risks and dynamic warning, to achieve a comprehensive evacuation of people at risk, forming a closed safety management system of "hidden danger occurrence - warning release - crowd evacuation The closed safety management system of "hidden danger release - feedback follow-up" is formed.

7. Home Gas Security System Based on Service Design Theory

7.1 Solution overview

The program focuses on gas security protection at the household level, introduces the concept of service design, and adopts "experiential" promotion and installation for the installation of home gas alarms, so that the product can quickly cover the user range, and further provides customized security services such as monitoring, early warning, and data sharing after the user has experienced the practicality of the product, through the coupling of home gas leak monitoring and insurance security services, we can achieve the timely treatment of home gas leaks and the construction of a coordinated risk security system.

7.2 Methodology and technology path

The method and technology path are shown in Figure 13.

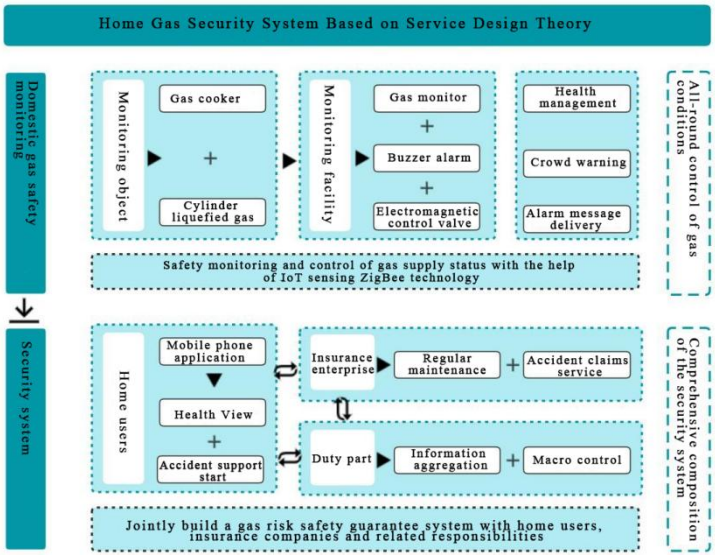

Fig. 13 Technology Roadmap

7.3 Implementation program

7.3.1 Home gas safety monitoring

For the monitoring of gas pipeline network for household users, gas sensors and beeping alarms are set up in the kitchen, and in addition, electromagnetic control valves are set up at the end of gas pipelines or cylinder liquefied gas and linked with sensors, both of which are incorporated into the backstage management system of Scheme 1 together with the city gas pipeline network for control.

The operation process is as follows: Firstly, the gas concentration in the air is monitored by the MQ-2 gas-sensitive sensor, as shown in Figure 11. Secondly, the signal obtained from the monitoring is converted into an electrical signal through a sampling circuit, and the resulting electrical signal is identified using a ZigBee terminal device control circuit, as shown in Figure 14.

If the identification shows that the gas concentration exceeds the standard, the buzzer on the terminal device will sound to warn the surrounding personnel, while the signal will be transmitted to the ZigBee coordinator, which will control the relay switch, and the relay will control the gas solenoid valve to close to prevent further leakage leading to more serious accidents. The GSM module receives the relay information and delivers alarm information to the backend management system and the insurance company, and sends it to the maintenance personnel in the form of dispatching orders to deal with the situation on site; in addition, it delivers alarm information to the home user APP to inform the user of the home gas safety status, as shown in Figure 15 and 16.

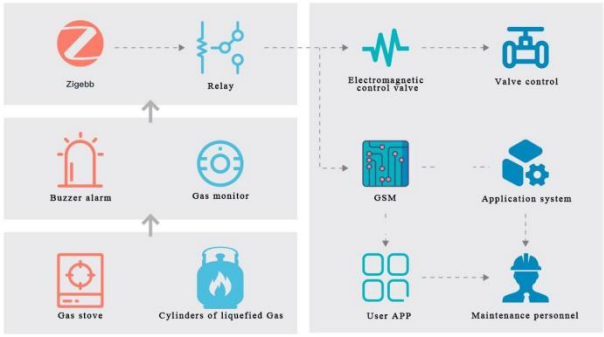

Fig. 14 Flow chart of home gas safety monitoring operation

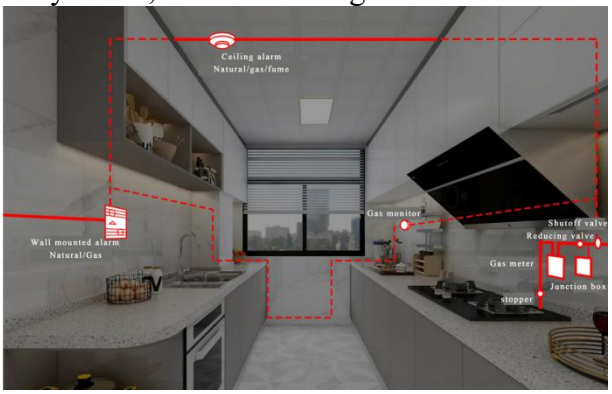

Fig. 15 Diagram of intelligent monitoring of household customer pipe network

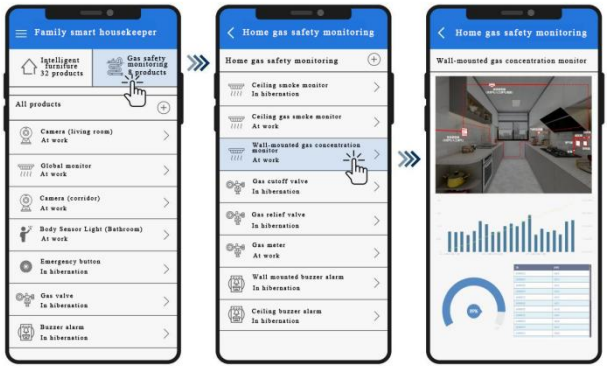

Fig. 16 Diagram of mobile app interface for home users

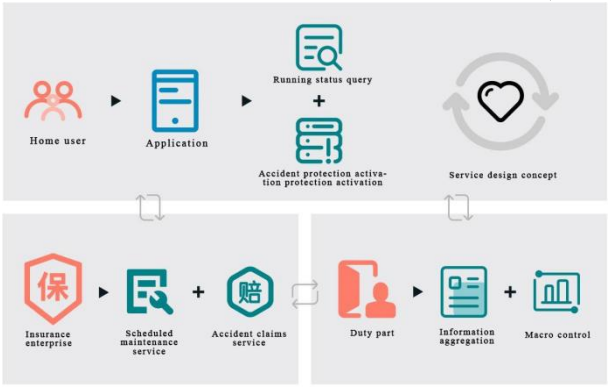

Fig. 17 Blueprint of security system services

7.3.2 Security guarantee service system

The security system of home gas security system is jointly constructed by home users, insurance companies and government departments, with home users as the center and insurance companies and relevant departments as the guarantee, to promote the safe operation of the home gas network, as shown in Figure 17.

At the home user level, at this stage, due to the high viscosity of cell phones, the implementation plan introduces the concept of service design and the introduction of a home gas security system with a cell phone APP as the controller, which makes it easy for users to view the monitoring screen and early warning information to understand the safety status of home gas. In addition, it can be linked in real time to insurance companies to start accident protection services to protect life and property.

At the insurance company level, the company collects monthly residential service fees from customers and gives them home gas monitoring sensors to provide safety maintenance services and accident claims services. Regular monthly visits are made to check the safety of home gas, and in the event of explosions, burns, poisoning, and other accidents caused by gas leaks that endanger personal safety and damage to household property, claims are initiated and compensated by the insurance company.

At the level of the responsible department, the gas safety monitoring at the household end is incorporated into the back-end management system built by Program I, and relevant information is summarized to facilitate the unified dispatch and macro control of the relevant departments.

7.4 Solution summary

The solution focuses on the problem of single mode of gas monitoring at the household level and the inability to solve hidden dangers in a timely manner. Based on the introduction of the service design concept, through the coupled operation of household gas leak safety monitoring and insurance safety services, the solution realizes the timely treatment of household gas leaks and the synergistic construction of a risk safety protection system.

8. Conclusion

The article focuses on gas safety issues and carries out research on intelligent Gas safety monitoring and early warning at the government, social, and household levels, and proposes a gas network visualization monitoring system based on IOT perception technology, a gas risk early warning evacuation system based on dual base station continuous tracking, and a home gas security system based on service design Three solutions are proposed for home gas security system based on service design theory, forming a closed-loop working system for gas safety monitoring and early warning, management and security with full coverage of government, society and home. The gas

safety monitoring and early warning management system provides a new system concept for the gas safety industry in the areas of government management, social early warning, and household security, and will bring a comprehensive gas safety monitoring and early warning and risk safety protection system with the following innovations:

8.1 Government management model innovation

Program I in the laying of sensing equipment, through the gas pipeline non-valve stage set gas monitoring sensors, pipe wall pressure sensors, to achieve rapid and accurate positioning of gas leaks, to solve the problem of tedious dragging through the gas well monitoring to deduce the leak point. It forms data management visualization, leakage analysis visualization, early warning control visualization, and builds a gas safety management system of dynamic safety supervision, normalized hidden danger investigation, and scientific special response.

8.2 Innovation in social warning methods

Program 2 adds early warning for people around the risk point of leakage to the traditional gas leakage warning method. When a gas leak occurs, the warning information is fed back to the application system, and based on GPS positioning technology, evacuation information is sent to the people around the risk point through the network base station with a plan of the surrounding risk points, and then risk release information is sent after the risk is handled. To achieve all-round coverage of early warning information, to avoid the loss of people's lives and safety to the greatest extent.

8.3 Innovation in home safety protection

Program 3 targets the monitoring of home gas network, setting combustible gas sensors in the kitchen and setting electromagnetic control valves at the end of gas pipelines or cylinder liquefied gas associated with detectors, both of which are incorporated into the backstage application management system together with city gas network monitoring to provide safety monitoring services for users. In addition, joint insurance companies provide safety protection services for users, forming a synergistic construction of a home gas safety monitoring and risk safety protection system.

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