Application Analysis on the Information Management System for Water Supply Network in Guangzhou

Chen Yuli, Wang Zhihong, Tu Yu, Wang Shen
School of Civil and Transportation Engineering
Guangdong University of Technology
Guangzhou, China
chenyuliabcd@163.com

Sun Wen
Control Center of Secondary Water Supply
Guangzhou Water Supply Company
Guangzhou, China
kwenfen@qq.com

***Abstract*—With the enlargement of water supply network scale and the complication of network topology structure, the related network management becomes more and more complicated. In that case the traditional manual modes and measures of management can not meet the requirement of "safe water utilization and high quality service" proposed by water enterprises. In order to improve the management level of water enterprises, it is imperative to establish a set of information management system for water supply network. According to the information management system for water supply network in Guangzhou, this paper, based on data research, introduces the general situation of the system, analyzes the present situation in the application process, explains the existing problems in details and proposes improvement programs preliminarily, providing a basis for the improvement of the information management system for water supply network in Guangzhou.**

Keywords-the information management system for water supply network; GIS; SCADA; integration; hydraulic model; monitoring station

I. PREFACE

Water supply pipeline is an important part of urban infrastructure and it is also the important basic information for urban planning, construction and management. With the rapid development of urban construction and the constantly increases of water consumption and network scale, water supply network has become a complex network with complex spatial and non-spatial information. Correspondingly, a lot of network data are needed to be handled timely and the management of complexity increases every year. However, the traditional manual modes and measures of management can not meet the requirement of "the water utilization and high quality service" for water enterprises. Additionally, the ability and efficiency of copying with emergency can not meet the necessity of high-speed urban construction [1-2]. Therefore, in the era of quick development of digital realization nowadays, in order to improve and enhance the management level of water enterprises, realizing the digital management, it is imperative to establish a set of management information system for water supply network which based on the Geographic Information System. It will bring the production and management level of urban water supply to a new height and lay a solid foundation for enterprise standardization.

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II. THE PROFILE OF INFORMATION MANAGEMENT SYSTEM FOR WATER SUPPLY NETWORK IN GUANGZHOU

The information management system for water supply network in Guangzhou is a system that consisted of computer software and hardware. Based on Geographic Information System (GIS), combined with Supervisory Control And Data Acquisition (SCADA) system, the information of pipelines and facilities are acquainted, storied, managed, analyzed, inquired, outputted, updated in the form of digital, using geophysical techniques, the mapping technology, computer technology, GIS technology, database technology and communication technology. Owing to the system, it provides accurate basis information of pipelines and facilities for staffs in water supply enterprise. It can also provide scientific basis for decision-making leaders and realize the operation services such as water distribution, network planning and design, pipeline repairment, network business collecting, network asset management and so on. It is a management system with various uses which can not only meet the needs of all sorts of daily business, but also support decision and analysis.

This system is consisted of GIS and SCADA system. ArcGIS ArcEngine 9.2 of Environmental System Research Institute (ESRI) is chosen as geographic information system platform and Oracle10GR2 is adopted as its database. The system structure is separated into three different cooperatively levels by the presentation logic, business logic and backend database. The function of presentation logic is the input and output of information and the business logic is for handling affairs while the backend database is for lasting preservation of the data in the business logic. The three levels connect each other through standard protocol TCP/IP under the network distributed environment. Based on the terrain gallery and pipeline database, this system integrates functions such as the basic information management, network information management, pipeline design update, the comprehensive analysis of the pipeline, the release of web information, network operation management, system maintenance management, etc. It has been invested into operation since 2004 and has realized the automatic and scientific management of water supply network. The system structure is as following in Fig. 1.

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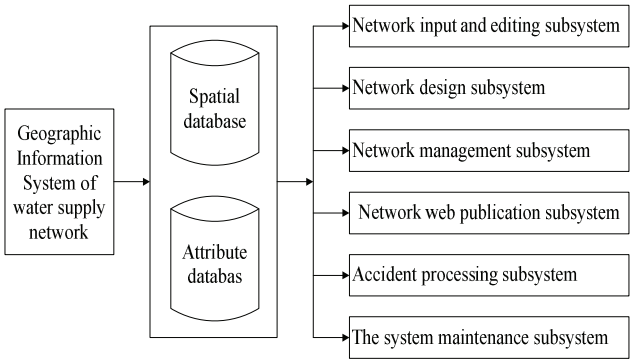

Figure 1. The structure of Geographic Information System of water supply network

It has been 30 years since the establishment of the SCADA system by GCI Science & Technology Co., Ltd in the 1980s. It has been upgraded many times, so its current system is stable, its data are almost intact and it has a relatively perfect maintenance management institution. SCADA system is formed by remote terminal (RTU), level control sites as well as the corresponding communication equipment and external devices. RTU, an important part of the SCADA system, is functional for reading and testing local data of the monitor equipment and accepting the remote telemetry command. The function of RTU is to monitor the acquisition and delivery of local data to accept and complete orders from the remote control and to accomplish the local control. Control center site is the control center of SCADA system, in which staff can undertake various visual operations for SCADA system through related software installed in control center. The Control center site has the function of collecting real-time operation parameters from RTU so as to conduct loading analysis, optimization scheduling, condition assessment, faults forecasting and analysis, comprehensive management to set remote commands to RTU and complete statistical reports, etc.

III. APPLICATION PTATUS OF THE SYSTEM

Owing to the construction and application of the information management system for water supply network and on the basis of the improvement of the maintenance and management level of existing water supply network and processing speed of on-site accident, Guangzhou water supply company obtains best operational economic benefits, realizing the standardization, scientization and modernization of the entire enterprise management. The current application status of the system is as follow:

1) The core network geographic information database for Guangzhou Water Supply Company is established. The system integrates the graphics information attribute data and even the daily maintenance data and user information of water supply network into a unified database achieving a unified platform for attribute data and spatial data and bringing the strong management functions of integrated office system of graphics and text into full play. The visualization of Geographic Information System of water supply network in Guangzhou Water Supply Company is showed in Fig. 2, displaying and managing all information of water supply network in Guangzhou.

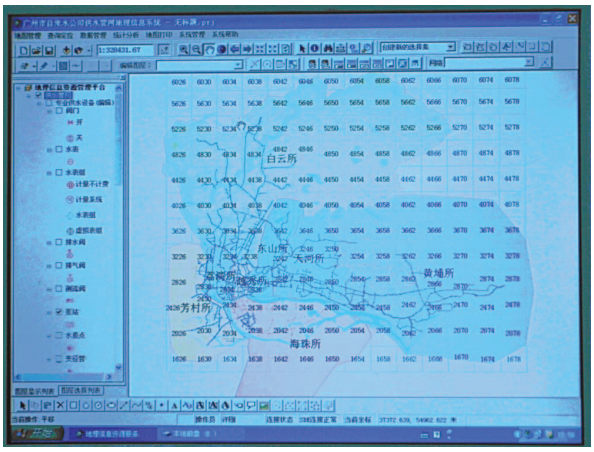

Figure 2. Geographic Information System of water supply network in Guangzhou Water Supply Company

2) The departments of planning, design, construction, maintenance, management and so on are all involved during water supply network management, realizing information sharing and unified management through network. In the premise of ensuring data integrity and consistency, related staff could quickly find the necessary information in terms of instant graphics, spatial distribution and attribute information of network by LAN or remote net to complete corresponding maintenance and administration no matter they stay in the office, the construction site, the repairing site or the remote site. The following Fig. 3 shows the application of Geographic Information System on information inquisition and location.

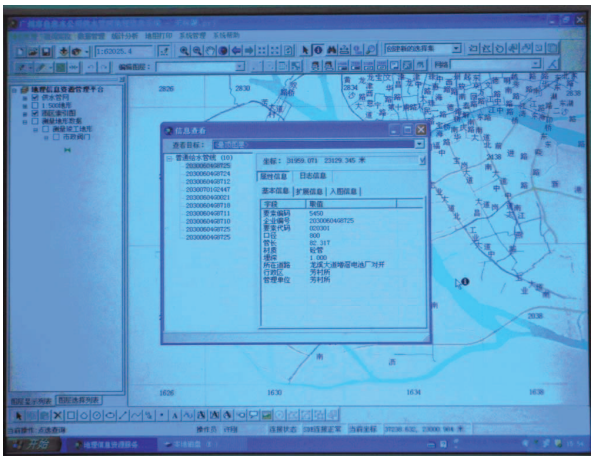

Figure 3. Information inqusition and location

3) Through the management of operation situation, antisepsis situation, service life of water supply network, the system could rapidly response to unexpected events, quickly find the point of fault, determine the sphere of influence and propose solutions.

4) SCADA system completes acquisition and transmission of real-time data of water supply network in Guangzhou including network monitoring stations data of the whole city, scheduling data of various water plants, pressure stations data and raw data of West River water management. With the combination of GIS and SCADA system, analyzing and calculating water distribution system timely, the dispatch and

command center could visually gain the pressure distribution and properties of each station of the whole network on the pipeline map, providing scheduling basis for safe water utilization.

5) Through incorporating the network planning and design in Geographic Information System of water supply network, the designer could use the latest data in the network geographic information system when they design for water supply project. They also could easily query and compare various network data, then complete the design. The design can be modified directly by data maintenance department in accordance with the as-built drawings after the completion, and then inputted into the database center to avoid data distortion in repeated mapping.

The information management system for water supply network in Guangzhou has become a synthesized information management system with supply network design, operation, management, maintenance, network resource analysis, accident disposing and auxiliary decision supporting.

IV. EXISTING PROBLEMS OF THE SYSTEM

With the development of science and technology, requirements to the information management system for water supply network are also enhanced. So there are various drawbacks for the information management system in the application process. Based on researching and analyzing the data of water supply network in Guangzhou, the drawbacks of the information management system for water supply network in Guangzhou are summarized. Meanwhile, the preliminary improvement programs are proposed. The details are as follows:

A. GIS and SCADA System runing Independently and the Poor Intergration Effect of the Information Management System

GIS and SCADA system in Guangzhou are two independent, mature software systems. They run independently based on their own platform. GIS only provides a client for SCADA system. SCADA system, used for site monitoring and automation management [3-4], is instant data acquisition and supervisory control system. It could get real-time monitoring data through RTU, carry out automatic control of network site in local or remote site, comprehensively and instantly monitor water supply process and give necessary reference data for production, scheduling and management. But the data recorded by SCADA system changed over time. SCADA system could only provide what is happening in the network but predict what will happen. So it could not tell the operation situation of network running in different parameter for operator. Of course, it does not have analysis and decision support capabilities. In addition, the biggest limitation of SCADA system is lack of the ability to display spatial data. But GIS, as a new subject, combining with computer science, geography, mapping remote sensing, environmental science, urban science, space science and related disciplines, has the ability to display complex spatial data and effectively manage massive spatial data, topology and topological relations. However, it was possible that got and managed equipment's instant data through GIS since that is not the goal [5]. Since there is not data interface between databases of GIS and SCADA system, data format is different, it affects the mutual sharing of data between systems and the system's compatibility is poor. And as SCADA system is lack of the ability to display spatial data, the visualization of instant monitoring data becomes poor. Because of the poor integration between GIS and SCADA system, it reduces the efficiency and ease of use of the information management system for water supply network in Guangzhou. Therefore, to utilize equipment remote monitor, GIS and SCADA system need to be put together. Through collecting instant data with SCADA system and organizing the instant data, equipments' and facilities' spatial data, attribute data with GIS, it realizes the integration of the two systems.

A Shanghai Petrochemical Corporation [6] water supply system has established the information management system for water supply network which based on GIS and SCADA system. The system is consisted of data management center, SCADA data collection terminals and functional management platform. It implements the integration of GIS static data and SCADA system dynamic data, improves the quality of information in water supply system, enhances the basis of decision support, achieves the construction of the two systems' unified platform, realizes GIS and the SCADA system supplementary in the technology, strengthens on-site instant monitoring data visualization capabilities and greatly improves management and efficiency of water supply network.

In view of the application status of the information management system for water supply network in Guangzhou and Shanghai, it is necessary to study the integration of GIS and SCADA system for the information management system for water supply network in Guangzhou and achieves the integration of the two systems.

B. System Module in the Absence of Netmork Hydraulic Model

Water supply network is an important part in the water supply system. It is necessary for a manager to master dynamic operating conditions of water supply network in the water supply system management. With the development of urban and the sharply growth of urban water consumption, correspondingly, urban water supply network scale was expanding. Water supply network in Guangzhou has become a complex topology, a large, random changes strongly in water use, multi-objective operational control network system. Meanwhile, the quantity and pressure of network changed times and water supply network was a dynamic system. These created a great difficulty for hydraulic calculation and operation management of water supply network. But currently, the information management system for water supply network in Guangzhou only managed static data and provided location information and attribute information of network for managers. In the lack of hydraulic model of working conditions in real-time simulation module in the system module, managers can not grasp operating conditions of the dynamic water supply network comprehensively. It results in less than scientific, efficient and safe management and operation in the network, moreover seriously limits the economic benefits of water supply enterprises and the level of scientific and technological

progress. Therefore, to correctly analyze and completely grasp the operation of water supply system and ensure the normal operation of water supply system, we need to build a network hydraulic model. With the water supply network simulation system planning, design, management and operation scheduling on the network for scientific and information constructions, we can raise the overall level of water supply enterprises and service quality.

Water supply network hydraulic model is a mathematical model to express the real water supply network by a certain mathematical relationship and network topology relationship. It can be an entirety collecting fundamental equations of water supply network and a variety of dynamic and static information. This model combines with GIS and SCADA system, based on GIS providing static information and SCADA system providing real-time monitoring data. Ultimately it is simulated working conditions of the water supply system through a series of processes such as the model calculations, validation, verification, etc. However, the information management system for water supply network in Guangzhou is constituted by GIS and SCADA system, which creates favorable conditions for the establishment of water supply network hydraulic model. The hydraulic model that can fully grasp the situation of the water supply system, predict the influence on the system of transformation and maintenance of the network, analyze the reasons for pipe explosion and the impacts on the water supply surrounding areas. It provides a technical means for safe water supply, scientific decision, economic scheduling and optimal allocation [7].

C. Imperfect Function of the Localization of Pipe Explosion in System Module

Water supply network in Guangzhou has constructed for 100 years. With the corrosion and aging of part of network , the relatively slow speed of the network renovation and the damage of network caused by various environmental factors and human factors, it leads to the continue phenomenon of pipe explosion. The following Tab. I has shown the statistics of pipe explosion in Guangzhou for six years.

TABLE I. THE STATISTICS OF PIPE EXPLOSION IN GUANGZHOU

Year	Number of Pipe Explosion (Times)					
	Classify by reasons				*Total*	*Times per day*
	Human factors	*Non-human factors*				
		Annulations	*Constructions*	*Others*		
2004	271	461	69	4938	5739	16
2005	273	872	92	5470	6707	18
2006	230	650	68	5484	6432	18
2007	96	208	26	2877	3207	9
2008	153	2296	184	5839	8472	23
2009	20	1047	3	43	1113	3
Total	1043	5534	442	24651	31670	14

Note: There are missing data in 2007 and 2009.

Data from the table show that numbers of pipe explosion in Guangzhou are large which reaches thousand times per year and fourteen times per day. There are so many times of pipe explosion that the leakage of network is serious, a large number of clean is lost in vain which leads the waste of water resources, water quality of part of network is lower and the living of the people is affected in different degree. To reduce the rates of pipe explosion and accidents' losses, the water supply enterprise should enhance the checking work of pipe explosion, deepen the study of technology for rapid localization of pipe explosion, improve the timeliness and accurate of localization of pipe explosion to ensure safe water supply and the normal productions and lives of urban residents.

Although accident processing subsystem has a function of handling explosion accidents, this function is mainly applied after the accident. Then, the operators point out the locations of pipe explosion and utilize the water supply network information management system to simulate networks pipe explosion field and formulate the reasonable processing plan automatically (such as closing valve measure) so that eliminating malfunction promptly and educing the loss caused by blasting leakage accidents. However, the location of pipe explosion, determined by this function, which is only obtained by operators according the changing information in the system is not the real location of pipe explosion and the accurate of the localization of pipe explosion is poor. Secondly, the location of pipe explosion, provided by the people around the pipe explosion point after pipe explosion created effects, is the accurate location of pipe explosion, but the localization of pipe explosion is not timely with huge wastage of water and affecting the operation of the city. Therefore, it is necessary to further study of pipe explosion to improve the function of the localization of pipe explosion by means of water supply network hydraulic model and SCADA system. Through setting the monitoring stations which supervise the changes of the flow and pressure of pipelines before and after the accident of pipe exploring, adopting neutral net method to track and analyze networks which could reflect the implication relation of “pipe explosion of any point ”and the information of water supply network operation conditions such as the flow, pressure and flow direction, it could locate the actual place of pipe exploring timely and accurately based on neutral net to reduce the impact caused by the accident of pipe explosion and improve the safety and reliability of water supply network [8].

D. Arrangement for Hydraulic Monitoring Stations in the Lack of Optimization in SCADA System

To have a good knowledge of the operation situations of water supply network and conduct optimal scheduling and accident monitoring for water supply network, it is necessary to monitor the flow, pressure and other parameters of pipelines with certain monitoring equipments in the SCADA system. Setting up the monitoring stations of the flow and pressure of pipelines is a multiple objective decision making problem with ascertaining the number of monitoring stations and its locations. Because the number of the monitoring stations is related to investment costs, the rationally location of monitoring stations, under the constant total of it, can collect the information to the maximum extent which reflects the real-time changes of the flow and pressure of pipelines [9].

The SCADA system was established in the 1980s. Owing to the early foundation and the restrictions in technology and investment, we often choose the location of the monitoring stations with empirical methods of large random. The flow monitoring stations are usually set on the neighborhood of

water plant effluent points and large diameter pipes, the pressure monitoring stations are often set on the intersection of large diameter trunks, the water supply separatrix of water supply plants and control points with high elevation or low elevation. In the system, 181 monitoring stations have been set up with 6 in water plants, 28 in pressure stations, 2 in West River raw water, 1 in information monitoring stations, 2 in base monitoring stations, 142 in pipe networks. The distribution of monitoring stations is as showed in Fig. 4. With the enlargement of water supply network scale in Guangzhou and the complication of network topology structure, the presentation of monitoring stations that had set is poor and numbers of monitoring stations are not enough. It can not reflect the operation conditions of water supply networks through collecting the information of monitoring stations and affects the optimal scheduling and accident monitoring of water supply networks. Therefore, it is very necessary to optimize the monitoring stations in SCADA system with the method of optimization arrangement. Through optimizing the monitoring stations and arranging the monitoring stations on the place that could provides the state information of networks to the greatest degree [10], it could monitor the operation situation of water supply network comprehensively and instantly and provide a scientific basis for the optimal scheduling and accident monitoring of water supply networks.

Figure 4. The distribution of monitoring stations in SCADA system

E. SCADA System with Insufficient Monitoring Index and Number of Monitoring Stations of Water Quality

As the problems of water quality become increasingly prominent, people have been paying more and more attention to the security of urban drinking water. The water supply networks are impacted with interior and exterior factors such as network overhauling, pipeline corrosion, pipeline penetration, disinfecting the outgrowths, terror assaults and so on. As a result, water quality which is qualified in waterworks has been changed and contaminated with complex physical, chemical and biological changes in the process of transporting to the users. As with a survey to 36 cities accounting 44% of the gross all over the country, average turbidity of treated water is 1.3, but that of the network water increases to 1.6 with the color increasing from 5.2 to 6.7, iron from 0.09mg/l to 0.11mg/l and the sum of bacteria from 6.6cfu/ml to 29.2cfu/ml [11]. However, the state has promulgated a new water quality standard in 2006 in which the higher requirements are proposed for the monitoring and control of network's water quality. Adopting the manual inspection methods to monitor water quality exist shortcomings such as data deficiency, sampling limitations, data incontinuity and human manipulation errors. So intercalating water quality monitoring stations in the networks to ensure safe water supply seems much more important. But SCADA system in the very system mainly sets up hydraulic monitoring stations such as flow monitoring station and pressure monitoring station. As to water quality monitoring stations, only in 7 waterworks (monitoring pH, turbidity, ammonia nitrogen, dissolved oxygen, temperature) and networks (monitoring pH, turbidity, residual chlorine) respectively set up 7 monitoring stations and 4 stations (its distributing conditions shows in Fig. 4), the monitoring index and the number of monitoring stations of water quality are insufficient which makes the operator fail to master the real-time quality of water supply network timely and affects safe water utilization.

With the development of remote monitoring technology and the computer technology, the monitoring of conventional water quality has been easily tackled. Currently, most of the water supply enterprises choose residual chlorine, turbidity and pH as the online monitoring indicators and these three indicators can finely reflect the water quality conditions to some degree [12]. In our system, that three indicators are included, but to monitoring the water quality conditions of the water supply network better, other indicators such as conductivity, total organic carbon, color, temperature, ammonia nitrogen, dissolved oxygen and so on should be added selectively. Meanwhile, just as hydraulic monitoring stations, the amount and locations of water quality monitoring stations should be optimized using the method of optimization arrangement to make sure that the network system is under 24-hour-continuous-monitoring and the deciders can get the alarm information timely to response the water quality changes promptly and correctly. This is of great importance to the advancing of safe water utilization and the management and service level of Water Supply Company.

V. CONCLUSIONS

Both the systems of GIS and SCADA congregated, kinds of advanced technologies adopted, informationization, scientization and standardization achieved in deed, the information management system for water supply network in Guangzhou is a synthesized management system of water supply network design, operation, management, maintenance, resource analyzing, accident disposing and auxiliary decision supporting. However, along with the rapid development of technology and technique, corresponding demands for the information management system are higher and higher. The problems appearing in the information management system for water supply network in Guangzhou are inevitable and constant improvements are required in the coming days to enhance the management of networks, the applied operation of the system and the water supply service in Guangzhou Water Supply Company.

Informationization building in water supply corporations is a long-term and incessantly improving process, the realization

of the informationization platform for water supply network should follow the principles of master plan and procedure actualization and carry out data communion among the systems with functions complementing each other. Moreover, the informationization platform is not an unsophisticated computer system but a synthesized management system. Whether the system of informationization can exert its applied benefits, it depends on not only the construction of software and hardware but also on the combination of informationization and daily work. Strengthening the intercommunion between the practicality production and the informationization management department is to ensure informationization exerting its deserved benefit in principle.

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