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Automation project of the Baimaotang Hydraulic Hub

Weimin Wu[1*], Bihan Tao[2], Qingsong Wang[3]

[1]Changshu Municipal Administrative Service Center, Suzhou, China
[2]Changshu Hydraulic Engineering Construction Management Center, Suzhou, China
[3]Changshu Water Services Center, Suzhou, China

*Corresponding Author. Email: 12363499@qq.com

Abstract. With the rapid development of smart water conservancy, the application of automation technology in hydraulic hub projects has become a key factor in enhancing the efficiency of water resource management and ensuring project safety. Taking the Baimaotang Hydraulic Hub Project in Changshu City as an example, this paper mainly discusses the overall design and core functions of its automation system. Through the integration of a computer-based monitoring system, Local Control Units (LCUs), and intelligent analysis technologies, the project achieves real-time monitoring and automated control of key parameters such as the operating status of primary and auxiliary pumping equipment, water levels, flow rates, and gate openings. The system adopts a hierarchical and distributed architecture, combined with hydropower measurement and online monitoring technologies for unit status, which significantly improves the reliability and responsiveness of project operations while enabling fault diagnosis and intelligent early warning. In addition, the integration of remote video surveillance and security systems further enhances management efficiency, providing technical support for flood control, drainage, water environment improvement, and scientific water resource scheduling. Practice has shown that the automation construction of the Baimaotang Hub offers a valuable reference model for the intelligent upgrading of hydraulic projects in plain river network regions and plays an important role in promoting the high-quality development of modern water conservancy.

Keywords: hydraulic hub project, automation, intelligent monitoring, water resource management

1. Introduction

With the rapid advancement of information technology and intelligent equipment, the automation of hydraulic hubs has become a key approach to improving the efficiency of water resource management and advancing the development of smart water conservancy. The application of automation technology has significantly enhanced the operational efficiency and stability of hydraulic projects. Through real-time monitoring, intelligent diagnostics, and automated control, it not only reduces energy consumption and labor costs but also improves fault response speed, ensuring both operational safety and economic performance [1, 2]. From a technological perspective, the maturity of the Internet of Things (IoT), big data, and Artificial Intelligence (AI) provides strong support for real-time monitoring, intelligent scheduling, and risk early warning in hub operations. Li [3] analyzed the application of automation technologies such as GIS, BIM, and UAV systems in water conservancy and hydropower engineering, noting that these technologies can greatly enhance the convenience, construction efficiency, and cost-effectiveness of such projects. They also promote the intelligent upgrading of technical systems and facilitate the high-quality development of the water conservancy sector. From the perspective of development needs, automation construction is an inevitable choice for coping with extreme climate events and water resource shortages. Several scholars have pointed out that the root cause of safety risks in China's water conservancy projects lies in the outdated monitoring methods and management models, which still rely heavily on traditional manual operations. This dependency results in delayed decision-making when responding to emergencies such as heavy rainfall or droughts [4, 5]. Moreover, to accommodate future upgrades and continuous system renewal, newly constructed hub projects must comply with the framework of integrated automated information management systems [6]. In summary, under the dual drive of technological feasibility and national strategic demand, the automation of hydraulic hubs has become a crucial measure for achieving high-quality development in modern water conservancy.

2. Project overview

As an economically developed city situated in a plain river network region, Changshu features a dense and intricate water system with abundant water resources. The city's urban river network exhibits a typical circular and radial pattern, characterized by complex hydrological interconnections. In recent years, Changshu has faced dual challenges of water environment management and flood control and drainage, with three major problems standing out: First, due to the increasing frequency of extreme weather events in the Taihu Lake Basin and the higher standards for flood control, the city's existing flood control facilities are no longer sufficient to withstand heavy rainfall events comparable to those of 1991 and 1999. Because of the densely built urban area, embankment construction is infeasible, leaving potential safety risks in flood protection. Second, the city's capacity for hydraulic regulation remains inadequate. Water diverted from the Yangtze River into the urban area primarily drains away rapidly through the main channels, resulting in uneven water distribution among internal small and medium-sized rivers. It is therefore necessary to achieve scientific water allocation through the construction of flood control hubs. Third, water quality in the urban river network remains poor. Due to incomplete sewage interception and weak water circulation, over half of the city's rivers are classified as Class V or inferior Class V, with stratified flow widely observed. This severely restricts the development of water landscapes and the improvement of residents' quality of life. Comprehensive management of these issues is thus essential for ensuring urban flood safety and improving the aquatic ecological environment.

To address these problems, the Smooth Flow and Living Water Project was proposed to enhance the connectivity and regulation capacity of the city's primary water systems. By diverting high-quality Yangtze River water from Haiyangjing and Shanqiantang through scientific dispatching, the project aims to improve water circulation, increase environmental capacity, and enhance the self-purification ability of water bodies. Baimaotang is one of the five major Yangtze River-connected waterways in the Yangcheng region, jointly responsible for the water diversion and drainage of an area totaling 2,537 km². Its capacity for water regulation ranks second only to the Liuhe River among the five main channels. The Baimaotang Hydraulic Hub Project is an integral component of the Changshu Urban Smooth Flow and Living Water Project, undertaking crucial functions including urban flood control, drainage, water environment improvement, and the protection of the city's historical areas. To achieve coordinated control and regulation between flood prevention and water circulation in the urban area, an independent dispatch center has been established within the Baimaotang Hub management zone. This center, aligned with the goals of the Smooth Flow and Living Water Project, is responsible for constructing an intelligent platform that integrates flood control and water circulation management within the planned area. The Baimaotang Hydraulic Hub is located along the southern edge of Changshu's main urban district, adjacent to the Kun Cheng Lake Scenic Area and west of the Yushan Scenic Area, at the confluence of Baimaotang and the city moat. The specific location is shown in Figure 1.

Figure 1. Location of the Baimaotang Hydraulic Hub project

3. Overall design of the automation project

3.1. General design

The integrated automation system of the Changshu Baimaotang Hydraulic Hub adopts a computer-based centralized control system to realize comprehensive monitoring and intelligent management of the pump station's main and auxiliary equipment. The system's core functions include real-time detection and data acquisition of key parameters such as water level, flow rate, and gate opening. All signals collected from measuring instruments are efficiently processed and visually displayed through the computer monitoring system, providing reliable data support for automated control. The control system adopts a dual-layer architecture that integrates the central control room's supervisory computer (upper-level system) with Local Control Units (LCUs). This configuration not only meets the requirements for centralized management but also ensures the flexibility and reliability of on-site operations.

The pump station is equipped with a technical water supply system, a drainage system, a hydropower measurement system, and an online monitoring system for unit operation status. In the monitoring design, automation monitoring is primarily implemented in the pump chamber, inlet and outlet sluices, and their connecting sections, as required by the engineering conditions. The monitoring center is planned to be located within the management station. The automation monitoring system consists of two main components: hardware and software. The hardware is responsible for field data acquisition and control, while the software handles data analysis, management, and visualization. The system can perform periodic and selective measurements of all connected automation devices, continuously measure critical points, and process acquired data to calculate the required physical quantities. It also stores essential data, establishes databases, and outputs (displays, prints, or plots) necessary charts and reports. Furthermore, the system can conduct real-time analysis and evaluation of dam operation status based on monitoring indicators, quickly assess safety conditions, and issue alarms when measured values exceed permissible limits.

3.2. Monitoring and control principles

The monitoring and control system adopts a hierarchical and distributed architecture composed of the pump and gate control system and Local Control Units (LCUs). For general equipment, control functions are implemented through I/O interfaces of the LCUs; for devices equipped with built-in microprocessor or PLC control, communication and I/O integration methods are employed to connect them with the LCUs.

The LCUs are categorized as follows: three pump unit LCUs (one per pump), one general-purpose LCU, one technical water supply LCU, one hydraulic system LCU, one power distribution LCU, and one gate control LCU—totaling eight LCUs.

All field devices support both manual and automatic operation modes, with local/remote selector switches installed. In terms of control priority, local manual > LCU automatic > control room remote. When the upper-level supervisory equipment or network fails, the operation of pumps and related devices remains unaffected. Operators can still carry out normal pump and gate operations via the Human-Machine Interface (HMI) of the LCUs.

3.3. Monitoring system software configuration and functions

The monitoring system software configuration includes operating system software, support and application software, database software, and communication software.

The Local Control Unit (LCU) provides key functions such as real-time data acquisition and processing, operation monitoring, operation control, diagnostics and alarms, and network data communication. The upper computer system in the control room is responsible for the overall monitoring and management of the pump gates. Routine monitoring, control, and management of the pump gates are mainly performed on the upper computer. Its primary functions include real-time data acquisition and processing, operation monitoring, operation control, operation management, diagnostics and alarms, and network data communication with the superior monitoring center. Meanwhile, the integrated video surveillance system responds in coordination with the security alarm signals, quickly locating the alarm source, capturing live images, and transmitting them to the control room for storage and playback. The remote video monitoring system supports multi-screen real-time viewing, Pan-Tilt-Zoom (PTZ) control, intelligent alarm linkage, and remote video recording and playback. It also features multi-disk loop storage, motion detection, and hierarchical access management. Designed with a modular architecture, the system offers high flexibility, stability, and security, meeting the intelligent monitoring and management requirements for various application scenarios under wide-area network environments.

4. Main components of the automation design

4.1. Hydropower measurement system

The hydropower measurement system primarily includes the measurement of water level, pressure, and uplift pressure. Two submersible water level gauges are installed before and after the trash rack of the debris-cleaning machine to monitor water levels in real time and calculate pressure differentials. Radar-type water level gauges and staff gauges are used respectively on the inlet and outlet sides of the pump station to measure water levels. In total, six sets of pressure sensors are installed along the inlet and outlet conduits of the three main pump units to monitor channel pressure. In addition, eleven uplift pressure measuring points are arranged on the pump station's base slab (four on the inlet side, four on the outlet side, and three in the middle section), while three measuring points are set on the bottom slab of the regulating gate. All points are connected to the upper structure through DN50 steel pipes, and uplift pressure sensors transmit the collected data to the PLC system, enabling real-time monitoring of the structural safety condition.

4.2. Unit operation online monitoring system

The unit operation online monitoring system applies electronic and computer technologies to the operational management of equipment, allowing for stability assessment and fault diagnosis. Centered on mechanical fault diagnosis technology and supported by the Internet of Things (IoT), this system continuously monitors and records a wide range of operational data over time. The upper-level computer processes these data and converts them into corresponding values, graphs, and trend curves, allowing operators to fully understand, manage, and control equipment operation, identify faults, and take appropriate measures. This significantly enhances the level of operation and maintenance management.

The unit operation monitoring system consists of three main components: the sensor detection unit, the online vibration monitoring instrument, and the analysis and display unit (including software and servers). The system mainly performs on-site observation, display, and alarm functions, while the control room server integrates database management, comprehensive visualization, and intelligent analysis functions. The sensor detection unit employs high-quality, original imported acceleration-type vibration sensors. The online vibration monitoring instrument rapidly and synchronously receives monitoring data from all sensors, converts them into effective graphical and curve representations, and filters redundant data intelligently before storing the processed information in the database. This design assists operation and maintenance personnel in accurately assessing equipment status, effectively improving management efficiency, and ultimately achieving unattended operation as well as cost reduction and efficiency enhancement.

5. Conclusion

The Baimaotang Hydraulic Hub Project serves as a crucial initiative for scientifically improving regional water resource quality, ensuring the sustainable utilization of water resources, and meeting the growing demands of economic and social development. The project's primary functions include flood control and drainage, while also coordinating water resource regulation and environmental improvement. Through the integrated application of automation technologies, the project has significantly enhanced the operational efficiency and management capability of hydraulic engineering. The computer-based centralized monitoring system, combined with a hierarchical and distributed architecture of Local Control Units (LCUs), enables real-time monitoring and intelligent control of key parameters such as pump station equipment operation, water levels, flow rates, and gate openings. The implementation of the hydropower measurement system and the unit operation online monitoring system provides essential data support for the safe operation of the facility, while fault diagnosis and early warning functions further improve system reliability. Additionally, the linkage between remote video surveillance and the security system optimizes management processes, effectively reducing labor costs and energy consumption.

The practical experience of this project demonstrates that the application of automation technology in hydraulic hubs can substantially enhance flood control and drainage capacity, improve water environment quality, and enable scientific scheduling of water resources. Its successful implementation offers valuable insights for the intelligent upgrading of water conservancy projects in plain river network regions and provides a technological model for the advancement of smart water management. In the future, by further integrating artificial intelligence and big data analytics, the level of system intelligence can be deepened to address more complex water resource management challenges, thereby promoting the high-quality development of the water conservancy sector.

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