ISSN:2790-1688 Volume-10-(2024)

Research on reservoir dispatching system based on digital technology

Jianhong Guo

Hangzhou reservoir management service center;

jq7276@163.com

Abstract. With the development of digital technology, the automation and intelligence level of reservoir dispatching systems need to be improved urgently to cope with the challenges brought by complex hydrological conditions and climate change. This study designed a complete reservoir dispatching system based on advanced monitoring and communication technology. The system integrates ultrasonic/radar water level gauges, rainfall gauges and other sensors, and realizes real-time data transmission through GPRS/CDMA/3G/4G networks to ensure the accuracy and timeliness of information. By establishing accurate hydrological models and optimization algorithms, dynamic monitoring and prediction of reservoir water levels and flows are achieved, and dispatching strategies are optimized to achieve efficient coordination of multiple goals such as flood control, irrigation, water supply, and power generation. It is expected that the implementation of this system will significantly improve water resource management efficiency and emergency response capabilities.

Keywords: digital technology; reservoir dispatching system; automated monitoring.

1. Introduction

As the impact of global climate change intensifies and the demand for water resources continues to increase due to population growth, reservoirs, as important water resources control facilities, have become an important symbol of measuring the progress of a country's water conservancy science and technology. In this context, the reservoir dispatching system based on digital technology emerged as the times require and has become a key technical support to improve the efficiency of water resources management, ensure water resources security, and meet the needs of the ecological environment [1] . Digital technology, including information collection, transmission, processing and analysis technology, provides unprecedented accuracy and response speed for reservoir dispatching. The application of these technologies not only enhances the reservoir's response ability to complex hydrological conditions, but also improves the automation level of dispatching and ensures the scientificity and real-time nature of dispatching decisions [2] . This research aims to provide a set of practical solutions for the field of reservoir dispatching and provide reference for scientific and technological development trends in related fields.

2. Application of digital technology in reservoir dispatching

2.1 Overview of reservoir dispatching system

The reservoir dispatching system is a core component of modern water conservancy management. Its main function is to achieve reasonable distribution and regulation of water resources, ensure water supply safety, and meet multiple water needs such as flood control, power generation, and irrigation. As shown in Figure 1, the system mainly consists of upstream monitoring and data collection, including water quality monitoring, meteorological monitoring and water level monitoring. These monitoring data are transmitted to the central processing unit in real time through local area network (LAN) or virtual private network (VPN) [3] . Based on the collected data, the central processing unit conducts data analysis and processing through advanced program logic controllers (PLC) and remote terminal units (RTU), in conjunction with real-time monitoring and data acquisition systems (SCADA), to achieve precise control of the reservoir gates. . The downstream of the system is the human-computer interaction interface, including the operation interface and decision support module for engineering and technical personnel, as well as the strategic assessment and decision-making auxiliary information provided to the management [4] . Through these interactive interfaces, technicians can adjust scheduling strategies in real time based on system feedback, while management can make strategic decisions based on long-term planning and risk assessment information provided by the system.

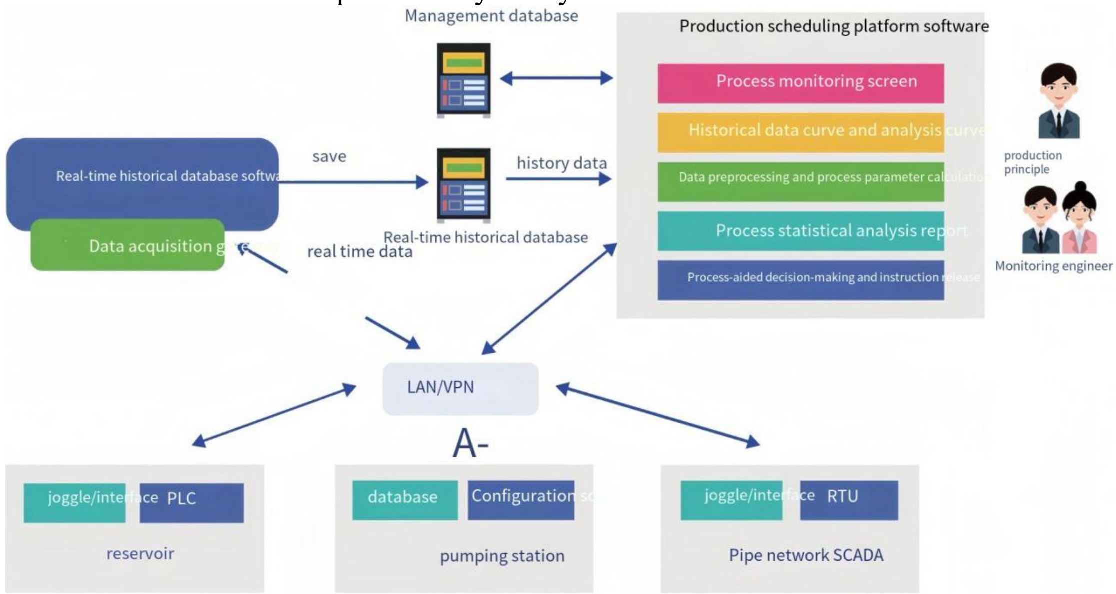

Figure 1 Composition of reservoir dispatching system

2.2 Introduction to key digital technologies

In the reservoir dispatching system, key digital technologies play a vital role. The most important thing is automated monitoring technology, which monitors water level, water quality, flow and other parameters in real time through sensors installed at key points of the reservoir, providing an accurate data basis for dispatching decisions. Secondly, data transmission technology ensures that monitoring information can be quickly and securely transmitted to the central processing unit through a local area network or virtual private network. In the central processing unit, the advanced program logic controller and the remote terminal unit are the core of intelligent control. They are responsible for executing data processing and responding to instructions, directly affecting the operation of facilities such as reservoir gates [5] . In addition, the real-time supervisory control and data acquisition system (SCADA) provides a comprehensive monitoring platform for the system, which can not only display real-time data, but also execute complex control algorithms and handle fault diagnosis. Finally, the human-machine interaction interface (HMI) presents intuitive data and control interfaces to operators and decision-makers, supporting fast and accurate decision-making and scheduling operations.

3. Design and implementation of reservoir dispatching system based on digital technology

3.1 System architecture design

As shown in Figure 2, this study designed a reservoir dispatching system based on digital technology, and its system architecture design uses advanced monitoring and communication technology. The system consists of ultrasonic/radar water level gauge, water surface friction monitoring terminal, rainfall gauge, Beidou satellite terminal, surveillance camera, GPRS/CDMA/3G/4G communication network, server and mobile application. Water level monitoring terminals are deployed at key locations in the reservoir to monitor water level changes in real time; rainfall gauges are used to record rainfall data. All monitoring terminals can achieve precise positioning through Beidou terminals and transmit data to the server through various communication networks. The monitoring center can receive data and surveillance videos in real time through mobile applications to ensure comprehensive and immediate control of the reservoir conditions.

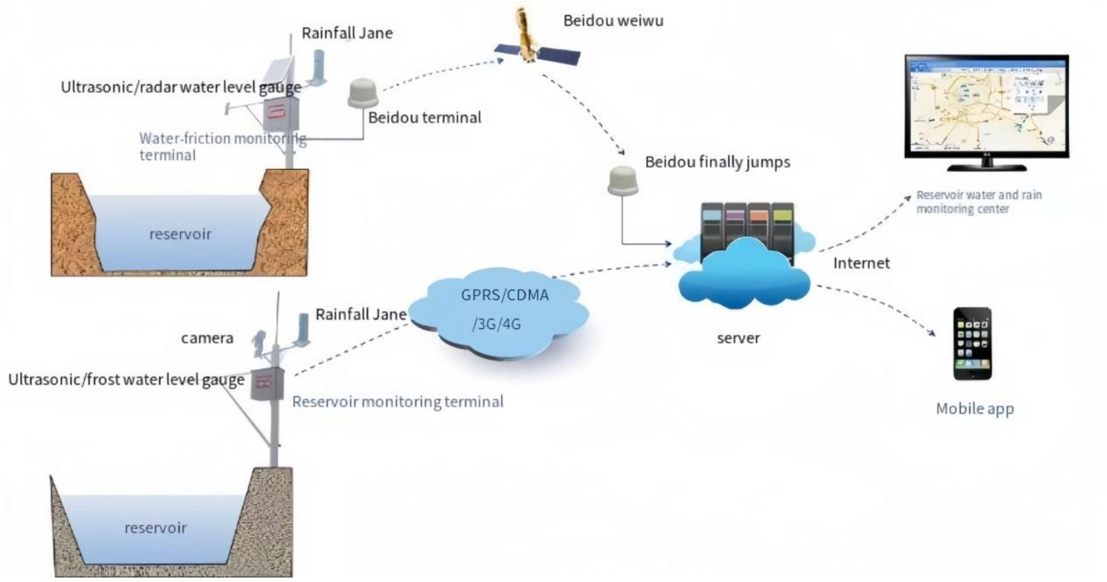

Figure 2 Architecture of reservoir dispatching system based on digital technology

3.2 Application and implementation of key technologies

3.2.1 Integration of automated monitoring technology

The system's automated monitoring technology utilizes a variety of sensors to achieve high-precision data collection. For example, the ultrasonic water level meter and radar water level meter used in the system can measure water level changes with an accuracy of ±1mm. Through sensors installed at different locations, all-round monitoring of the reservoir water surface is achieved to ensure the comprehensiveness and accuracy of the data. Combining the water level data H and the flow calculation formula (1):

$$Q = A(H) \cdot V(H) \quad (1)$$

Among them, A(H) is the cross-sectional area corresponding to the water level, and V(H) is the flow rate at the water level. The system can calculate the instantaneous flow rate of the reservoir in real time.

Monitoring technology also includes automatic monitoring of water flow velocity. Through friction sensors set on the water surface, the friction changes on the contact surface between the fluid and the sensor are monitored, and then the water flow velocity V is calculated. This data is combined with the water level gauge data and applied to the flow calculation formula (2):

$$Q = A \cdot V \quad (2)$$

Among them, A is the cross-sectional area of the river, which can realize real-time dynamic monitoring of flow. All monitoring data are transmitted to the server in real time through the GPRS/CDMA/3G/4G network, and then transmitted to the monitoring center and mobile application platform through the Internet.

3.2.2 Model-driven scheduling strategy

The system's model-driven dispatch strategy relies on advanced hydrological models and data processing algorithms. Using the measured data D as model input, the system first predicts the reservoir water level changes in the future through the hydrological model M. This model can express formula (3) as

$$M(D) = H_{t+1} \quad (3)$$

where H_{t+1} is the predicted future water level.

The system also combines the prediction of rainfall P output by the weather forecast model and the actual reservoir capacity C to calculate the possible inflow flow. Apply the continuity equation formula (4):

$$C = A \cdot H + Q_{\text{in}} - Q_{\text{out}} \quad (4)$$

Among them, Q_{in} and Q_{out} represent the inflow and outflow flow respectively. The system calculates the response of the reservoir under different forecast rainfall scenarios and makes corresponding dispatching strategies. Based on the above model and data, the system uses the optimization algorithm O to determine the optimal scheduling plan. Formula (5) can be expressed as:

$$O(M(D), P, C) \rightarrow S \quad (5)$$

Among them, S is the dispatching strategy, including the timing of opening the flood gate and the flow volume. Dispatch strategy S will ensure that the reservoir can maximize the benefits of its multiple uses such as water supply and power generation while preventing flooding.

3.3 System interface and interaction design

Based on automated monitoring technology, the system interface and interaction design are closely integrated with actual operational needs. The interface design follows the principles of intuition and simplicity, emphasizing data visualization and immediate response. Users can clearly observe the real-time data R through the graphical interface (GUI), including the current water level H, incoming flow Q_{in} and outgoing flow Q_{out} . The system interface adopts a modular design, and the data display area S_d , control command input area S_i and system status prompt area S_s are organically integrated.

Specifically, the data display area S_d displays the time series diagram of reservoir water level H and rainfall P in real time to help users intuitively grasp the hydrological change trend. The control command input area S_i provides user interface input, such as setting target water levels H_{target} and scheduling flow rates Q_{dispatch} . The system uses feedback control formula (6) to adjust the flood discharge strategy to achieve precise reservoir management: $F\left(H, H_{\text{target}}, Q_{\text{dispatch}}\right)$ (6)

The system status prompt area S_s is based on monitoring data and model prediction results, using algorithms A_s to evaluate the system status S_{state} , $A_s(M(D), H) \rightarrow S_{\text{state}}$ and prompts users to perform corresponding operations through color coding or alarm mechanisms to ensure the safety and timeliness of operations.

For the data interaction and command response process, the system has designed an efficient data processing process P_{data} and instruction issuance process P_{command} . The data processing process ensures that the raw data collected from the sensors D_{raw} are processed $P\left(D_{\text{raw}}\right)$ and displayed on the interface in an optimized manner, minimizing delays. The instruction issuance process ensures that operating commands on the user interface C_{ui} can be quickly converted into control signals for downstream equipment S_{device} , ensuring the immediacy and accuracy of system scheduling.

4. Testing and evaluation of reservoir dispatching system

The study selected a large reservoir located in East China for on-site testing of the digital reservoir dispatching system. The test aims to verify the reliability, accuracy and scheduling optimization efficiency of the system and ensure that the system design meets the strict requirements of engineering applications. Before testing, the deployment and configuration of the system was first completed to ensure that all monitoring equipment was in optimal working condition. At the same time, through collaboration with the Reservoir Management Bureau, safety measures during the test were established.

Under natural conditions without human intervention, collect baseline data such as water level H, flow velocity V, and rainfall P for a week to establish a hydrological database before the test. Through simulation input, the system's responsiveness and accuracy in the data display area D_{display} , control command input area C_{input} and system status prompt area S_{status} are tested. The water level and flow data measured by the system are compared with the standard hydrological instrument data, and the accuracy difference is ΔH calculated ΔQ . Implement simulated rainfall events, perform flood discharge operations according to the dispatching strategy S provided by the system, and monitor the consistency between the actual flood discharge flow and the system dispatch recommended flow.

Table 1 Reservoir dispatching system test results

test number	Water level monitoring accuracy (cm)	Flow velocity monitoring accuracy (cm/s)	Communication delay (ms)	Scheduling command response time (s)	System stability evaluation
001	±0.05	±0.314	120	0.8	good
002	±0.08	±0.533	115	0.7	good
003	±0.04	±0.218	130	0.9	excellent
004	±0.06	±0.621	110	0.6	good
005	±0.07	±0.432	100	1.0	good

As shown in Table 1, the test results show that the reservoir dispatching system performs well on key performance indicators. High-precision monitoring ensures the accuracy of operations, while fast communication and response capabilities ensure the timeliness of dispatch. The stability of the system also indicates that it is able to work continuously and reliably.

5. Conclusion

This study successfully designed and implemented a reservoir dispatching system based on digital technology. The test results showed that the system met the predetermined design requirements in key performance indicators such as water level and flow rate monitoring, data transmission, and command response, demonstrating high accuracy and rapidity. Responsive characteristics. The evaluation of system stability also proved its reliability under various operating conditions. This innovative dispatching system provides strong technical support for efficient and accurate water resources management and is expected to play an important role in improving the efficiency of reservoir operations in flood control, irrigation, water supply, and power generation. In the future, with the continuous advancement of technology and the in-depth application of big data, artificial intelligence and other fields, this system is expected to be further optimized, its level of intelligence and automation will be even higher, and its contribution to the field of water resources management will also continue to expand. .

References

[1] Zhang W, Huang Y. Using big data computing framework and parallelized PSO algorithm to construct the reservoir dispatching rule optimization[J]. Soft Computing, 2020, 24: 8113-8124.

[2] Khadonova SV, Ufimtsev AV, Dymkova S S . “Digital Smart Airport” System Based on Innovative Navigation and Information Technologies[C]//2020 International Conference on Engineering Management of Communication and Technology (EMCTECH). IEEE, 2020: 1-6.

[3] Li X, Luo J, Li Y, et al. Application of effective water-energy management based on digital twins technology in sustainable cities construction[J]. Sustainable Cities and Society, 2022, 87: 104241.

[4] Xiaoyi Z, Dongling W, Yuming Z, et al. IoT driven framework based efficient green energy management in smart cities using multi-objective distributed dispatching algorithm[J]. Environmental Impact Assessment Review, 2021, 88: 106567.

[5] Zhang Z, Jing R, Lin J, et al. Combining agent-based residential demand modeling with design optimization for integrated energy systems planning and operation[J]. Applied Energy, 2020, 263: 114623.