Research and Application of Reservoir Safety Monitoring System for Intelligent Water Conservancy

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Abstract: Safety monitoring systems are an important part of intelligent water conservancy projects. Based on the overall scheme requirements of intelligent water conservancy in the new era, we analyzed the new requirements of the current safety monitoring system. Intelligent perception, infrastructure, data resources, intelligent analysis and application display of reservoir safety monitoring system under the background of intelligent water conservancy are described respectively. Combined with the exploration of the intelligent safety monitoring system of Hekou Village reservoir, the functions of the system are introduced for further improvement. References and suggestions are provided for the construction of safety monitoring systems for intelligent water conservancy projects.

1. Introduction
Intelligent water conservancy [1] refers to the application of cloud computing, big data, Internet, mobile Internet, artificial intelligence and other newly developed information technologies in water conservancy projects, such as rivers, lakes, groundwater reservoir, hydropower station and water gates, as well as water storage, drainage and other water management activities through perception, networking, information sharing and intelligent analysis. These efforts would serve as basis for the supervision and management of modern water conservancy, inundation and drought prevention, as well as intelligent processing, decision-making and associated services of water conservancy.

Reservoir safety monitoring system for intelligent water conservancy has a wide range of applications in business with high technical demands. The underlying data can be obtained through thorough perception of automation equipment, and the monitoring results can be extracted, analyzed and timely transmitted and published by using the new generation of information technologies, so as to ensure safe operation and management of intelligent, scientific and economically-efficient reservoirs [2]. Compared with the traditional digital security monitoring, which carries out only post-processing and analysis of the monitoring data, intelligent monitoring combines with theories and methods of intelligent analysis, and proposes predictions based on historical data, and gives early warning in time.

2. New Requirements for Intelligent Water Conservancy for Safety Monitoring
Intelligent water conservancy has put forward new requirements on the construction of reservoir safety monitoring system. The safety monitoring system is supposed to be three-dimensional, one-stop and
intelligent. To achieve this, a strategic system should be adopted to solve newly-emerging problems and realize new leapfrogs [3].

1) Full three-dimensional coverage
Reservoirs that needed to be monitored in an intelligent way usually feature a large area, and complex geological and topographic conditions. The comprehensive perception of safety monitoring system should integrate various channels for monitoring. On the basis of the original monitoring techniques, the earth space information technology should be fully integrated to cover the whole reservoir and river basin, so as to construct a multi-dimensional safety monitoring system to collect data from both the sky and the earth. Through the construction of intelligent sensor information network, it provides comprehensive, accurate, dynamic and timely safety monitoring spatio-temporal data for intelligent water conservancy.

2) Requirements for one-stop production capacity
Safety monitoring and supply service needs to improve the top-level design, and establish one-stop supply and service capabilities integrating monitoring design, system construction, data collection, data sorting, data analysis and data mining.

3) Requirements for specialized intelligent services
Intelligent application is the ultimate goal of intelligent water conservancy. The security monitoring system should be based on the spatio-temporal information platform framework of intelligent water conservancy, and with the help of cloud computing and big data technology, an in-depth mining on the massive monitoring data of heterogeneous multi-sources should be conducted. Finally, comprehensive monitoring data sources, real-time collection, automatic collation, intelligent analysis, knowledge services, multiple expressions and network collaboration will be achieved. It provides convenient, efficient and intelligent safety monitoring services for intelligent water conservancy [3].

3. General characteristics and framework of intelligent safety monitoring

3.1 General characteristics of intelligent monitoring
Intelligent monitoring system can add, delete and modify monitoring points and parameters as needed, which is an extensible and improvable system. It is compatible, inclusive, unified and coordinated. The system uses the current information technology while taking into account the trend of future technologies to accommodate the need for update. It meets the demands for real-time monitoring of the reservoir to detect abnormal conditions in a timely manner.

3.2 The overall framework of intelligent monitoring system
As an important subsystem of intelligent water conservancy, intelligent safety monitoring system has no construction standard. Based on the specific construction planning objectives of the intelligent water conservancy, the design of the technical scheme is carried out according to relevant norms and standards. The construction of intelligent safety monitoring system relies on the intelligent water conservancy infrastructure as well as software and hardware, thus promoting efficiency and lowering cost. The intelligent safety monitoring system of reservoirs, assisted by advanced information technologies such as intelligent perception, big data analysis, cloud computing, heterogeneous network integration, BIM+GIS and artificial intelligence, could fully perceive the structured and unstructured data of reservoirs, ensuring rapid response, scientific decision-making and collaborative management.
4. Examples of intelligent monitoring construction of reservoirs

4.1 Project overview
Hekou Village reservoir is located at the exit of the gorge in the last section of Qinhe river, a first-grade tributary of the Yellow River. It is a key project to control the flood and runoff of Qinhe river and an important part of the flood control system in the lower reaches of the Yellow River. Hekou Village dam covers a basin area of 9223km². Hekou Village reservoir is rated Level 2 in terms of scale and grade-II as an engineering project, consisting of concrete rockfill dam, No.1 spillway, No.2 spillway, diversion power tunnel, spillway and hydropower station.

4.2 Key technologies of intelligent monitoring system
(1) Full perception
Reservoir safety monitoring mainly include external deformation, internal deformation, seepage and seepage pressure, stress and strain, environmental quantity and so on. The monitoring system integrates Beidou satellite, unmanned aerial vehicle, monitoring sensor and manual inspection. The data is collected by layers. Monitoring parameters, such as displacement, settlement, stress and strain and seepage, are collected in a real-time manner that go from the sensor, data collection module, data automatic collection device to the central monitoring station. The database in the central station server allows sharing of resources such as data, parameters and other information. The administrative host or the superior authority can access the database remotely on the Internet. Field management personnel can process parameters, databases and other operations through the software, which, by giving different levels of permission, facilitates the utilization of the database by personnel from different levels.

(2) Infrastructure
The automatic safety monitoring system of Hekou Village reservoir adopts a fully distributed and open network with intelligent node control while the automatic data collection system is based on the Ethernet fiber network [6].

The standard RS232/RS485 interface of each field data acquisition unit (MCU) is converted to RJ45 Ethernet interface through serial port server, and independent and unique static IP address is set
on the serial port server so that each MCU can conduct network addressing through TCP/IP protocol. In order to ensure reliable long-distance transmission and improve the ability of the network against interference, single-mode optical fiber is adopted as the communication network medium between test stations and between test station and sub-station. The computer in the centralized control center and the MCU of each test station allows the mutual conversion between Ethernet electrical signals and optical fiber signals through the optical fiber transceiver. The safety monitoring system of Hekou Village reservoir adopts a three-layer C/S and B/S hybrid structure, namely the three-layer structure consisting of data platform, business service and human-machine interface.

(3) Data resources
Data resource layer [7] mainly includes three parts: 1) data aggregation platform. Middleware technology is applied to realize heterogeneous information aggregation of multi-system and data management based on distributed protocol. 2) comprehensive database. Integrated management of safety monitoring, water condition, water quality and other data along with geographical data as well as documentation work together to form a unified information management database. 3) database management and operation maintenance. The database allows remote backup to enable mass data storage and ensure data security; by integrating the system and data resources, it can not only reduce the cost of data management, but also ensure the integrity and consistency of the data.

(4) Intelligent analysis
Detailed monitoring indicators are set up for each monitoring items and monitoring points for abnormality evaluation of real-time monitoring data through the background data analysis. Combined with the existing model, the system compares real-time monitoring data with historical data for intelligent analysis, which would automatically inform corresponding management personnel of any abnormalities, thus allowing intelligent analysis and notification.

(5) Application display
The measurement points of the project including safety, water condition, gate, water quality and ecological flow and other monitoring indicators were classified by GIS to establish vector layers, which were superimposed on the map layers and connected with the spatial information management database to form an overall picture of the reservoir. Through an electronic map that can be scaled and shifted with various parameters for selection, the reservoir could be monitored in a real-time manner along with descriptions of the overall evaluation of the reservoir.

4.3 Main functions of intelligent monitoring

(1) Basic service
① Automatic data collection and storage: functions including real-time information collection, distributed remote measurement control, fault diagnosis of sensors and data collection devices, data inspection in the process of data collection, alarm for out-of-limit data and other functions.
② Manual data entry and storage: keyboard entry, file import, special procedures loading and other ways allowing artificial data collection and storage in the database.
③ Results calculation and processing: Through the design formula in the system, the original measurement values can be directly converted into the monitoring results, and error or error data can be identified and eliminated automatically and manually.
④ Graph drawing and qualitative analysis: the system designed the duration curve, spatial distribution diagram, correlation analysis diagram and statistical table for characteristic values, which can directly show the structure of the basic nature and safety of the measured objects.
⑤ Basic information management: the system provides the display of basic information, such as engineering attributes, events, drawings of main buildings, management organization and personnel information, GIS maps and so on.
⑥ User rights management: the system sets permissions according to the user right policy, allowing users at different levels to access the system.

(2) Intelligent analysis and management
① Analysis and quantitative analysis: modeling based on multiple linear stepwise regression, partial least-squares regression, the statistical model, hybrid model and neural network to study the influence of various factors (such as water level, temperature, rainfall, etc.) on the hydraulic structures, including deformation, seepage and stress strain as well as the scale of the influence, providing basis for structure safety assessment and prediction.

② Evaluation of the safety of structures: based on the theories and expertise of dam engineering and rock-soil mechanics, a three-level evaluation system for local anomalies of structures and the overall safety of the project is established, and the analysis and evaluation of the monitoring results obtained are drawn up[7].

③ Prediction of structure safety: based on numerical simulation and historical monitoring result model stored in the system model database, the trend of structure property and safety under specific conditions are predicted, and early warnings will be given according to the prediction, providing decision support for project operation and maintenance.

(3)Intelligent application
Mobile application: it enables relevant personnel to obtain key monitoring data and deliver early warning in a prompt manner so as to facilitate timely investigation, early warning release and emergency disposal by engineering personnel. It can also use the mobile Internet terminal system for emergency training.

4.4 For further improvement
Data mining and fusion analysis can be introduced to determine the authenticity of monitoring data. For example, covariance crossover algorithm can be used for data fusion and evaluation of the same index measured in different time periods and places in safety monitoring. For abnormal data, support vector machine and D-S evidence theory can be used for this purpose. The matrix decomposition technique can be used for heterogeneous data fusion of multi-level monitoring data from different departments. In addition, it is necessary to make assessments based on water conservancy expertise. By integrating information technology, data mining and expertise for analysis and decision making, the internal rules of water resource data will be better understood so as to identify the authenticity of data and improve its accuracy [4]

5. Conclusion
Intelligent monitoring involves every link of the safety monitoring system. Only by adopting advanced information technology, full perception, intelligent analysis and scientific decision-making can modern reservoir safety management be realized. The article first briefly introduces the function and requirements of the safety monitoring system of the intelligent water reservoir. Then based on the Hekou Village reservoir in Henan Province, the paper introduces the design of the system and its application, the modeling analysis and quantitative analysis, safety evaluation of the structure, safety forecast, early warning and emergency management, mobile applications as well as information release. The paper then points out defects of the system in need of further improvement. The system can effectively manage the safety monitoring of large reservoirs and provide powerful technical support for further analysis and decision-making.

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