Monitoring System Design for Intelligent Hydraulic Safety Based on the IoT

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Abstract: In order to improve the safety operation management of hydraulic structures in hydropower stations, this paper analyzes the status and shortcomings of hydraulic safety monitoring automation system, and puts forward the design idea and scheme based on IoT. The intelligent connection of hydraulic monitoring equipment is realized by optimizing the design of sensing collection, communication network, monitoring application and information security of the system. By coordinating the monitoring, configuration and management of each monitoring terminal equipment, and using cloud computing technology to calculate, analyze and evaluate the monitoring data in real time, the intelligent online monitoring of hydraulic structures is realized, so as to ensure the safe and efficient operation of hydropower station infrastructure.

1. Introduction

Since the traditional dam safety monitoring automation system has been used for decades, the long-term operation of the system leads to the problems of slow operation speed and low efficiency. With the rapid development and progress of information technology, some of the technologies are relatively backward, and the system function and performance cannot meet the requirements of the current hydraulic safety information and intelligent management and control. Due to the large scale of hydropower projects, especially the hydraulic structures of pumped storage power stations scattered in location, various in types and complex in structure, many difficulties confront the implementation of safety monitoring projects, such as scattered measuring points, no stable electricity supply, unattended. Limited by the traditional technology and cost factors, some monitoring projects fail to be automatic, which hinders the comprehensive and timeliness improvement of safety monitoring and is not conducive to the operation safety management of hydraulic structures.

Data acquisition is essential for hydraulic safety monitoring. With many objects, data acquisition is a very typical and terminal rich application scenario of IoT. At present, most of the applications based on the IoT realize the collection of monitoring data. At present, most of the applications based on the Internet of things realize the collection of monitoring data, and further analyze and sort out the data, and give early warning, but the feedback, control and intelligent management of the collection equipment...
still need to be improved [1]. The application and development of the IoT is closely related to the construction of smart grid [2]. With the development and gradual maturity of the IoT technology, the hydraulic safety monitoring system is upgraded and optimized by using the IoT technology, and the intelligent degree of the system is improved through the application of new technology, so as to enhance the comprehensiveness and convenience of safety monitoring, and improve the work efficiency and management level of hydraulic safety management to support the digital and intelligent development needs of hydropower stations and pumped storage power stations.

2. Status Analysis

2.1 Perception Collection
The output signal of the monitoring sensor is mainly analog quantity. Due to its low digitization degree, each type of signal instrument corresponds to an acquisition module, which is lack of generality. Due to the lack of standardized protocol in information collection, the data message format of manufacturers’ equipment is different from each other; the measurement signal type and supporting communication mode of the equipment are single, the integration is low, the volume is large, and the adaptability of engineering application is poor, which is not conducive to the unified management of the equipment. Most of the hydraulic monitoring instruments and equipment are installed in high humidity or field environment, the environmental conditions are bad, and the operation and maintenance of the system equipment is difficult.

2.2 Communication and Transmission
The local communication network is generally RS485 with bus topology structure. Part of the main network adopts ethernet, and the interactive mode adopts reply or self-report mode. The communication rate is low, the efficiency of the master-slave polling interactive mode is not high, and the data acquisition and transmission delay are often large, which is difficult to meet the needs of hydraulic safety online monitoring. In addition, it is difficult to implement wired communication in slope, wild mountain and other parts, and some remote parts are limited by communication, so remote automatic monitoring has not been realized.

2.3 Data Application
The existing monitoring system mainly focuses on the preliminary analysis of monitoring data, and lacks in-depth analysis, evaluation and other advanced applications of data. The real-time analysis is not high enough, and the intelligent level is also low. It cannot find problems in time and give fast feedback, and it has not yet reached the requirements of online monitoring and early warning.

2.4 Information Security
At present, some wireless transmission data of hydropower station security monitoring system are not encrypted, and are vulnerable to interference, eavesdropping and tampering. Some monitoring systems operate as independent LAN, and are not connected to the information intranet. There is a risk of data leakage, which needs to be solved urgently.

3. Design Ideas
With the help of the advanced IoT technology, the hydraulic safety monitoring system is improved from the local perception layer, network layer, platform layer and business application layer respectively to realize the efficient interconnection of various monitoring equipment, unified data collection, information security interaction and online monitoring and evaluation.

1) Standardize the interface and data format of sensors, collectors and other sensing devices, shield the underlying network differences, eliminate the things that cannot be connected due to the differences in data format; adopt appropriate networking technology, expand the coverage of monitoring automation, and strengthen online monitoring. Improve the ability of edge computing, improve the efficiency of data
processing, realize the scene linkage, such as automatic trigger encryption monitoring, linkage alarm or control when the data is abnormal.

2) Establish a cloud support platform integrating data collection, storage, exchange, analysis and service, fully collect all kinds of monitoring information resources, and realize intelligent applications such as online monitoring, analysis and evaluation, prediction and early warning, decision support of hydraulic structure health status, so as to make project safety management unified, reliable, timely and controllable, efficient transportation and management, convenient and smooth information service, and support hydraulic safety intensive and professional management of monitoring.

3) It provides an end-to-end trusted environment for the IoT. From the aspects of physical security, boundary security, application security, data security, host security, network security, terminal security and security management, it carries out the overall security protection for the terminal layer, network layer, platform layer and application layer, so as to realize the terminal trusted, reliable transmission and controllable boundary, and ensure the safe operation of hydraulic safety monitoring business.

4. System Design
According to the basic architecture of the IoT system, the hydraulic safety monitoring system can be logically divided into perception layer, network layer, platform layer and application layer (as shown in Fig.1).

4.1 Perception Layer
The sensing layer mainly includes field sensor, collector, intelligent acquisition terminal, local communication, edge gateway and so on, which realizes the holographic perception of hydraulic structure performance. At the perception level, we should try to use integrated, low-power, networked intelligent sensors or collectors, combined with intelligent acquisition terminal and edge gateway, to process and analyze all kinds of perception information, realize the autonomous operation of local monitoring area, and transmit the acquisition and processing results to the data center through the IoT management platform, and accept the remote monitoring of the IoT management platform. The cost of information collection, transmission and operation and maintenance is reduced. The perception layer is designed as follows:

1) For the dam, plant and other monitoring parts, the location of the station is relatively fixed, and the power supply and communication conditions are good. The intelligent universal data acquisition terminal can be used to realize the automatic data acquisition of various instruments. It can adapt to different communication networking modes such as wired and wireless, and access to the IoT management platform for remote management. This method has the characteristics of strong versatility, fast measurement speed, fast transmission speed, long-term stability and reliability.

2) For the slope, reservoir and other monitoring parts, the monitoring points are scattered, and the power supply and communication cable laying are difficult. The wireless acquisition terminal with low power consumption ad hoc network can be used, which integrates acquisition, processing and transmission. The battery power supply or auxiliary external DC power supply can be used, and the IoT management platform can be accessed through the edge gateway, or the IoT management platform can be accessed directly through the low power consumption remote wireless network. Remote wireless data acquisition is realized. This method is easy to install, debug and low cost.

3) For appearance deformation monitoring, such as static leveling, tension line, vertical line, tilt, etc., low-power wireless intelligent sensor can be used, which integrates sensing, processing and transmission. Battery power is used to realize periodic automatic monitoring, automatic trigger recording and data processing. Through the edge gateway access to the IoT Management platform, low-power wireless monitoring can be realized. This method has the characteristics of easy installation, fast deployment, less implementation cost and easy to realize online monitoring.
4) For other existing monitoring projects or subsystems, such as vacuum laser collimation and deformation measurement robot, they do not have the ability to directly access the IoT. Through reasonable division, edge gateway can be deployed in the monitoring area to realize the collection of subsystem data and transmit the data to the data center. This method has the characteristics of strong compatibility and low cost of access transformation.

4.2 Network Layer

The network layer mainly adopts the power data network and the special transmission network for hydraulic monitoring automation to carry the business. According to the environmental conditions of different structures and different parts of the site, suitable data acquisition and transmission methods are adopted. The network layer is designed as follows:

1) Low power local area ad hoc network based on ZigBee, Lora and other technologies has been widely used. The network coverage of NB-IoT of telecom operators has been gradually improved, and its high availability and low power consumption characteristics have been more and more applied. It is suitable for low-power, low-speed and low-frequency data transmission applications of wireless acquisition terminals and wireless intelligent sensors. With the continuous improvement of Beidou technology and the continuous reduction of communication costs in China, the communication based on Beidou short message will also be more applied in the safety monitoring of hydropower stations.

2) In recent years, the power wireless private network technology based on 4G has developed rapidly. The network has high security, reliability and maintainability. It supports the unified bearing of broadband, narrowband, acquisition, control and other services. It provides a new technical means for security monitoring service access. It is suitable for the high-speed, large amount of data and high frequency data of intelligent acquisition terminal and edge gateway Transport applications. With the
acceleration of 5G network deployment process, 5G will become an important supporting technology in the future.

4.3 Platform Layer
The platform layer mainly includes IoT management platform and data platform. The IoT management platform realizes the centralized management of monitoring terminal and edge gateway, as well as the data analysis and processing of each device, and forwards the data to the data platform. The data platform is responsible for the centralized storage of data and provides data subscription service to the application layer. The IoT management platform needs to support the unified monitoring, configuration and management of monitoring terminal and edge gateway equipment, realize data collection and standardized processing, support remote iterative upgrade of equipment application, and support data access of stock business system, etc.; from the preliminary analysis of the demand for measuring point scale and data calculation of hydraulic safety monitoring, the data platform generally does not need to be established separately. The existing data center of power enterprises can be used.

4.4 Application Layer
The application layer is built on the platform layer, through the remote monitoring technology, real-time monitoring data, real-time monitoring missing data, and monitoring and fault diagnosis of monitoring equipment status. The intelligent recognition algorithm of abnormal data is adopted to realize the automatic recognition of abnormal data; the monitoring data is comprehensively analyzed and evaluated through the analysis, evaluation and early warning technology, and combined with the inspection information for analysis and processing, and the early warning information is finally determined and released through SMS devices, mobile applications, etc. The application layer mainly includes online monitoring, hydraulic safety monitoring and management, hydraulic safety analysis and evaluation and early warning, hydraulic safety supervision and management, etc.

1) Online Monitoring
Through the IoT management platform, remote control of local monitoring equipment, real-time monitoring of the status of monitoring equipment, and fault diagnosis can be carried out, so as to reduce and shorten the time and scope of equipment maintenance, quickly restore the normal operation of equipment, and improve the availability of the system.

2) Hydraulic Safety Monitoring Management
The hydraulic monitoring management function is user-oriented and provides a unified hydraulic safety monitoring management interface, through which the main information of hydraulic safety monitoring, the real-time monitoring values of key parts of hydraulic engineering and the inspection of hydraulic structures can be displayed directly. It can query the current measured value, historical data, change trend of measured value and the engineering position information of the measured point, and realize the data analysis report, information query and manual record information submission, so as to meet the needs of remote control and management of the system.

3) Safety Analysis, Assessment and Early Warning
Based on hydraulic prototype monitoring, hydraulic safety analysis and evaluation realizes the whole process processing of safety monitoring information of measured objects such as dam, plant and slope, integrates information resources such as model base, real-time base, history base and method base, and obtains basic understanding of historical operation behavior of measured objects by means of comprehensive analysis and reasoning based on theoretical knowledge and practical experience of experts to estimate the safety status of monitoring objects, predict the future (or under specific conditions) safety status, and feedback the above recognition, evaluation and prediction results, so as to provide decision support for project operation scheduling and management.

4) Hydraulic Safety Supervision and Management
According to the current national and industrial standards, information entry, key node monitoring, document query and filing are carried out for the process and results of safety supervision, such as registration application, registration change, inspection and evaluation, audit and evidence collection,
etc. The main functions include registration information editing and query, automatic monitoring of registration process, registration task reminder, and automatic push of warning reminder information based on mobile terminal.

5. Application Effect

The advantages and application effects of the intelligent hydraulic safety monitoring system based on this design are as follows:

1) Make full use of the advantages of IoT technology, expand the coverage of automatic monitoring, further improve the integrity, real-time and effectiveness of data collection, realize the comprehensive perception of hydraulic safety monitoring information, and realize the online control and unified management of all hydraulic monitoring equipment through the IoT management platform.

2) By strengthening the edge computing and localizing the monitoring data, the abnormal monitoring data can be found actively, and the early warning information can be pushed in time to reduce the bandwidth requirements of data communication network; and the hydraulic safety monitoring information can be inquired through multiple terminals to master the operation status of hydraulic structures, so as to improve the efficiency of hydraulic monitoring and achieve cost reduction and efficiency increase.

3) Through the in-depth calculation and analysis of the monitoring data, a number of intelligent decision-making functions such as on-line safety monitoring, state assessment, fault analysis and positioning, fault maintenance and auxiliary linkage strategy of hydraulic structures are realized, so as to improve the timeliness of response to safety emergencies of hydraulic structures, and enhance the intelligent level of hydraulic safety management and the safe and economic operation level of production.

4) The construction of hydraulic safety online monitoring system is more convenient, easy to realize the remote technical support of the system, reduce the cost of system implementation and operation and maintenance, and realize the joint management and control of cross regional and multi project.

6. Engineering Examples

At present, the hydraulic safety monitoring system based on this design scheme has been applied in a water conservancy project in Jiangsu Province. The project mainly includes control gate, two-way pumping station and auxiliary River Diversion Project, and the project grade is grade II. The main goal of the hub is to expand the outlet of regional flood water discharged to the Yangtze River, improve the regional flood control and waterlogging removal capacity, give consideration to regional water supply and improve water environment, and promote regional economic and social development.

The project is mainly equipped with monitoring items such as bottom plate stress and strain, bottom plate base stress, base seepage pressure, joint opening and closing degree, wing wall earth pressure and environmental factors, and installation of buried monitoring sensors such as strain, non-stress, reinforcement, osmometer, joint, earth pressure and water-level gauges. The project design adopts 15 portable smart universal data acquisition terminals (as shown in Fig.2), which are powered by lithium batteries, and access to the cloud connected physical platform through mobile NB-IoT network using MQTT protocol. The terminal is arranged in each monitoring section and connected to various sensors of the section to realize the sampling, conversion and processing of the sensing signal. Then, the data is sent to the IoT platform through the wireless network, and transmitted to the message queue through the rule engine, and stored in the data platform after certain evaluation rules cleaning.
The monitoring application platform is developed with micro service architecture. With the help of cloud computing, it improves the system’s computing power and load elasticity, supports horizontal performance expansion and high concurrency, and supports online and offline data flow. The platform realizes the real-time collection, calculation and analysis of monitoring data, real-time warning push and equipment management, etc. It can browse the monitoring data, generate reports, graphic curves, reports, etc. by using the browser, and can control and manage the terminal equipment to realize the monitoring of the equipment. Through the supporting mobile app, the terminal equipment can be registered, debugged, monitored, consulted data, received early warning, and convenient for monitoring, operation and maintenance.

7. Conclusion
Hydraulic safety monitoring system is an important business system to ensure the operation safety of hydropower station and pumped storage power station infrastructure. Aiming at the problems existing in the current hydraulic safety monitoring system, this paper uses the IoT technology to optimize the design of sensing collection, communication network, monitoring application and information security of the system. Through this design, the intelligent level of hydraulic safety monitoring and management will be improved, which can timely grasp the hydraulic safety status, find danger, and carry out real-time warning, so as to effectively reduce the hydraulic safety risk, avoid engineering safety accidents, further promote the safe production and reliable operation of hydropower station, and realize digital and intelligent operation of hydropower station and pumped storage power station management is of great significance.

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