Research on quality control and reliability evaluation method of water pressure real-time detection system

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Abstract: The real-time water pressure detection system is of great significance in the fields of water resources management, water supply safety and water conservancy project monitoring. However, the quality control and reliability evaluation of the system still face many challenges. In this paper, the quality control and reliability evaluation methods of water pressure real-time detection system are studied. Firstly, a set of quality control methods is proposed, including selecting high-precision sensors, constructing a stable communication network, analyzing and processing data, and regularly calibrating and maintaining, so as to improve the accuracy of monitoring data and the stability of system operation. Secondly, a set of reliability evaluation method is developed, and the reliability level of the system is scientifically evaluated by using the indicators of system reliability, mean time between failures (MTBF), mean time to repair (MTTR) and failure rate, through actual operation data and fault simulation test. The experimental results show that the proposed method can significantly improve the data accuracy and reliability of the system, and provide a scientific basis for the optimization and upgrading of the real-time water pressure detection system.

1. Introduction

Real-time water pressure detection system plays an increasingly important role in water resources management, water supply safety and water conservancy project monitoring. These systems provide accurate and timely data support for relevant departments by monitoring the changes of water pressure in real time, which is helpful to find and deal with potential abnormal water pressure in time and ensure the stable operation of water supply system. However, there are still many challenges in quality control and reliability evaluation in the practical application of water pressure real-time detection system [1]. On the one hand, due to the influence of sensor accuracy, data transmission stability and data processing algorithm, the monitoring data of the system may have errors or fluctuations, which will affect the accuracy and reliability of the data. On the other hand, the long-term operation of the system may face the interference of various environmental factors and human factors, which will lead to the decline of system performance or failure, and then affect the normal operation and monitoring effect of the system [2].

Therefore, it is particularly important to study the quality control and reliability evaluation method of water pressure real-time detection system. This paper discusses how to effectively control the quality of water pressure real-time detection system to ensure the accuracy and reliability of monitoring data. At the same time, how to evaluate the reliability of the system is studied to provide scientific basis for the maintenance and management of the system.

2. Quality control method of water pressure real-time detection system

2.1. Sensor technology

Choose a pressure sensor with high precision, high stability and strong anti-interference ability to ensure accurate measurement in complex environment. For example, MEMS pressure sensors or ceramic capacitive pressure sensors can be selected, which usually have good long-term stability and low temperature drift characteristics [3].

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Sensors should have wide measuring range, high resolution and fast response characteristics to meet the needs of different water pressure monitoring scenarios. For example, for the water supply system in residential areas, a pressure sensor with a range of 0-1 MPa and an accuracy of ±0.1%FS may be needed [4]; For industrial water or fire water system, it may need a larger range, such as 0-10 MPa or even higher, and it also requires high precision.

According to the characteristics of water pressure distribution and monitoring requirements, the position of sensors should be arranged reasonably, and sensors should be installed at key nodes such as the entrance, exit and branch points of the pipe network [5]. In cold areas, it is necessary to consider the influence of seasonal temperature changes on the equipment and take anti-freezing measures to prevent the sensor from failing due to icing. Using wireless transmission technology can reduce wiring cost and increase layout flexibility, but we must also pay attention to signal coverage and possible interference to ensure the stability and reliability of data transmission.

2.2. Remote monitoring system

Build a stable and flexible communication network, support wireless (such as cellular network, Wi-Fi, LoRaWAN) or wired (such as Ethernet, optical fiber) technologies, and choose the most suitable communication mode according to specific needs [6]. It is recommended to adopt dual-link redundancy design, that is, to use two different communication means at the same time, so as to automatically switch to another line when one line fails. In terms of data security, SSL/TLS protocol encryption and digital signature technology are used to ensure the security of data transmission and prevent information from being tampered with or leaked [7].

The design of remote monitoring platform needs to cover real-time data display, historical data query and alarm functions, and can develop user interface through Web technology and manage data by using database system. On the platform architecture, micro-service architecture is helpful to improve scalability and maintenance convenience, and each functional module is regarded as an independent service and interacts through API interface. In addition, the platform must include a strict user rights management system, such as role-based access control (RBAC), to ensure that users can only access the content within their rights, and security can be enhanced through mechanisms such as OAuth2.0 [8].

2.3. Data analysis and processing

In order to improve the data quality, the original data are preprocessed, such as denoising and filtering, and abnormal data are identified and processed, including eliminating wrong data points and interpolating missing data. On this basis, an adaptive data analysis algorithm is developed to deeply mine and analyze the monitoring data, and automatically adjust the parameters according to the characteristics of water pressure change, thus extracting valuable information.

2.4. Calibration and maintenance

Make a detailed calibration plan, and re-calibrate all sensors at regular intervals to ensure that their readings are always in the best state. In addition to the routine annual calibration, calibration operations should be performed immediately after major maintenance. In addition, it is necessary to establish a sound maintenance system, regularly check whether the appearance of the equipment is damaged, whether the connecting wire is loose, etc., and replace the aging parts in time to prolong the service life.

3. Reliability evaluation method of real-time water pressure detection system

3.1. Reliability evaluation index

In the reliability evaluation of water pressure real-time detection system, a series of scientific and objective indicators are needed to measure the reliability level of the system. Table 1 below is the commonly used reliability evaluation index in this study.

Table 1 Reliability evaluation index of water pressure real-time detection system

Reliability evaluation index	describe	Impact on reliability
System reliability	Indicates the probability that the system will complete the specified function within the specified time and under the specified conditions.	Directly reflect the reliability level of the whole system.
Mean time between failures (MTBF)	Refers to the average time from one failure to the next.	The longer the MTBF, the higher the reliability of the system.
Mean maintenance time (MTTR)	Refers to the average time from fault discovery to fault repair after a system fault occurs.	The shorter the MTTR, the better the maintainability of the system, which has a positive impact on reliability.
fault rate	Indicates the probability of system failure in unit time.	The lower the failure rate, the higher the reliability of the system.

3.2. Appraisal procedure

In order to evaluate the reliability of the real-time water pressure detection system, this study not only collects and analyzes the performance parameters of the system in actual operation (including sensor accuracy, data transmission rate and system response time, etc.), but also compares them with the design indicators to determine the performance compliance, and calculates the reliability and failure rate; The method of fault simulation and test is also adopted, that is, artificially creating situations such as sensor fault or data transmission interruption to test the response and recovery ability of the system, and then recording the fault details and recovery time for calculating the key indicators of MTBF and MTTR.

3.3. Evaluation process

The reliability evaluation process of the real-time water pressure detection system in this study is shown in Figure 1, which is described as follows:

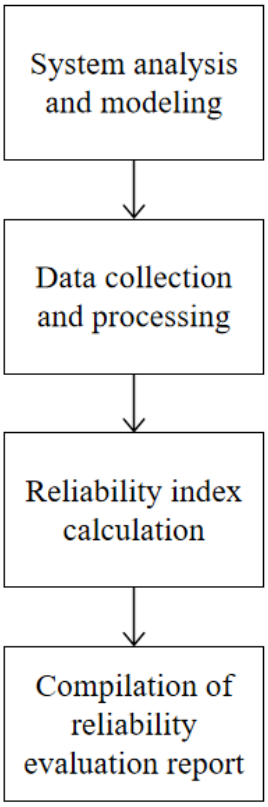

Figure 1 Reliability evaluation process of water pressure real-time detection system

1) System analysis and modeling: make a comprehensive analysis of the real-time water pressure

detection system to understand the composition, working principle and performance index of the system. According to the results of system analysis, the reliability model of the system is established.

2) Data collection and processing: collect the performance parameters and fault data of the system in actual operation, such as sensor readings, data transmission records, fault maintenance records, etc. Cleaning, sorting, and analyzing the collected data, and extracting effective information for reliability evaluation are essential tasks in the process.

3) Reliability index calculation: using the collected data and the established reliability model, the reliability indexes such as system reliability, MTBF, MTTR and failure rate are calculated. The calculation results are analyzed and compared to evaluate the reliability level of the system.

4) Compilation of reliability evaluation report: according to the reliability evaluation results, compile the reliability evaluation report, including evaluation purpose, evaluation method, evaluation process, evaluation results and analysis. Suggestions for improvement are put forward to provide scientific basis for system optimization and upgrading.

4. Experimental verification and result analysis

In order to verify the effectiveness of the proposed quality control and reliability evaluation method, a real-time water pressure detection system deployed in a city's water supply network is selected as the experimental object and tested in its actual operating environment, which includes water source, pumping station, pipeline and valve. A simulated water supply system was built in the laboratory for fault simulation. The experimental content covers the verification of quality control methods, that is, comparing the monitoring data before and after implementation to evaluate the accuracy and reliability improvement of data; And the verification of reliability evaluation method. By collecting the performance parameters and fault data of the system, the indexes such as reliability, MTBF, MTTR and fault rate are calculated and compared with historical data, so as to test the effectiveness of the new method.

Table 2 Comparison of key indicators before and after the implementation of quality control methods

Indicator project	Before implementation	After implementation	Ascending proportion
Sensor accuracy (%)	94.5	98.3	3.8%
Data transmission rate (kbps)	120.2	156.4	30.1%
System response time (ms)	250.0	187.5	25.0%
Noise data proportion (%)	5.2	1.3	75.0%
Abnormal data proportion (%)	3.1	0.8	74.2%

As can be seen from Table 2, after the implementation of quality control methods, all key indicators have been significantly improved. The accuracy of the sensor is improved from 94.5% to 98.3%, an increase of 3.8%, indicating that the accuracy of the monitoring data has been enhanced. The data transmission rate is increased from 120.2 kbps to 156.4 kbps, which is 30.1% higher, indicating that the data transmission efficiency has been significantly improved. The response time of the system is reduced from 250.0 ms to 187.5 ms, which is 25.0% shorter, reflecting the faster response of the system. In addition, the proportion of noise data and abnormal data decreased from 5.2% to 1.3% and from 3.1% to 0.8%, respectively, by 75.0% and 74.2%, which indicated that the data quality was significantly improved and provided more accurate basic data for the subsequent reliability evaluation.

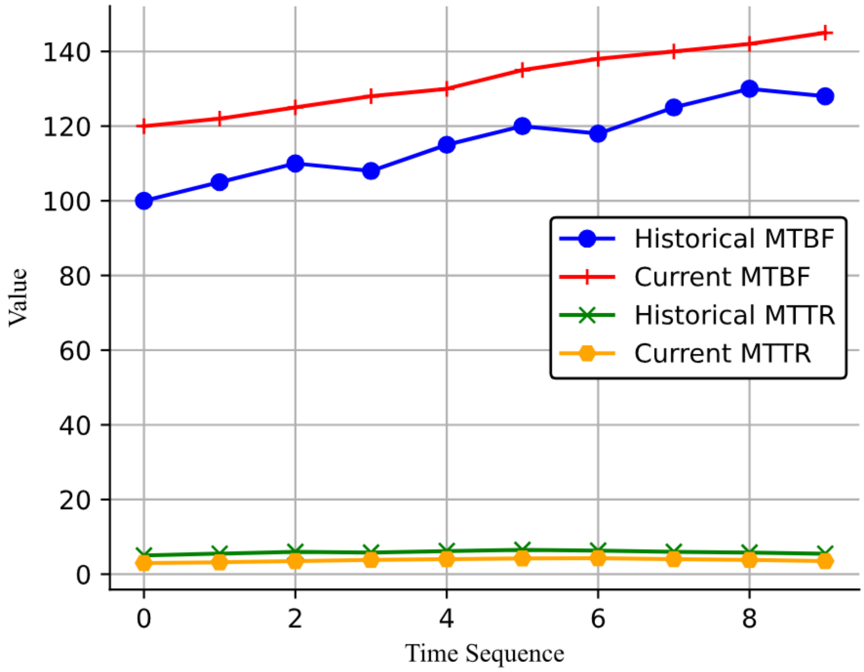

Figure 2 Results of reliability evaluation method

As can be seen from Figure 2, both the historical MTBF and the current MTBF are on the rise. The historical MTBF data fluctuates to some extent, rising from 100 to 130, for example, from 100 to 130. At present, the MTBF is relatively high, fluctuating from 120 to 145, and the overall value is higher than the historical MTBF, which indicates that the reliability of equipment may be improved and the time between failures becomes longer in the current practical application.

The historical MTTR fluctuates between 5 and 6.5, and the current MTTR fluctuates between 3 and 4.3. It can be clearly seen that the current MTTR value is lower than the historical MTTR, which means that in the current practical application, the repair time after equipment failure is reduced, which is caused by the improvement of maintenance technology, the optimization of maintenance process or the improvement of the maintainability of the equipment itself.

Table 3 Comparison of system performance before and after implementation of reliability evaluation method

Indicator project	Before implementation	After implementation	Change situation
System reliability (%)	92.4	96.7	Increase by 4.3 percentage points
Failure rate (times/hour)	0.032	0.018	Decrease by 0.014 times/hour

After the implementation of the reliability evaluation method, the performance of the system has been significantly improved (see Table 3). The reliability of the system has increased from 92.4% to 96.7%, an increase of 4.3 percentage points, which shows that the ability of the system in stable operation has been enhanced. At the same time, the failure rate is reduced from 0.032 times/hour to 0.018 times/hour, a decrease of 0.014 times/hour, which shows that the frequency of system failures is obviously reduced and the stability and reliability of the system are effectively improved.

Through the verification of this experiment, the following conclusions are drawn:

1) The quality control method proposed in this study can effectively improve the data accuracy and reliability of the real-time water pressure detection system.

2) The reliability evaluation method proposed in this study can measure the reliability level of the system scientifically and objectively, and provide scientific basis for the optimization and upgrading of the system.

5. Conclusion

In order to ensure the efficient operation of the water pressure monitoring system, this study adopts high-precision and anti-interference pressure sensors, and reasonably arranges the sensor positions and takes anti-freezing measures in cold areas to improve the accuracy and reliability of the data. A dual-link redundant communication network supporting wireless and wired technologies is constructed to ensure that the remote monitoring platform can transmit data stably and safely, provide real-time display, historical query and alarm functions, and ensure data security through strict authority management. In the process of data analysis, the data quality and the value of information extraction are improved by preprocessing the original data and developing adaptive algorithms. A detailed calibration and maintenance plan is made to prolong the service life of the equipment. In the aspect of reliability evaluation, system reliability, MTBF, MTTR and other indicators are used to measure system performance. The experimental results show that the effective implementation of quality control and reliability evaluation methods significantly improves the sensor accuracy, data transmission rate and system response time, reduces the ratio of noise and abnormal data, increases the system reliability from 92.4% to 96.7%, and reduces the failure rate from 0.032 times/hour to 0.018 times/hour, which greatly enhances the system.

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