Health Diagnosis and Safety Precaution of Water Conservancy Facilities Based on PHM

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Abstract: Safe operation of water conservancy facilities is the important condition to safeguard safe operation of hydraulic engineering, thus health management of water conservancy facilities can be ignored. In this thesis, the author applies PHM to health management of water conservancy facilities, constructs health diagnosis and safety precaution system of water conservancy facilities based on PHM, analyzes the system framework and functions, and provides reference for safe operation of hydraulic engineering in China.

1. Introduction

Hydraulic engineering is crucial to flood control and drought relief, water resource regulation, people’s livelihood guarantee, and ecological civilization construction. At present, the inspection on water conservancy facilities often apply regular inspection, which finds out damage or defects. Then, products are detected, replace accessories and supplement consumptive materials by aiming at relevant problems, resulting in waste of various resources and unsuccessful maximum benefit development of resources. Reinforcing life cycle management water conservancy facilities can effectively lengthen service lifetime, thus its value and function will be maximized to realize optimal configuration and utilization of resources[1]. Prognostic and health management(PHM) is used to management of water conservancy facilities, can diagnose health state of water conservancy facilities and predict possible problems, so as to change the traditional “breakdown maintenance” into “beforehand maintenance” and “state-oriented maintenance” and effectively safeguard operation safety of water conservancy facilities.

2. Brief introduction of PHM

PHM deploys lots of sensors on the physical entity and uses Internet of Things or other advanced information acquisition technologies to gain mass data of physical equipment, constructs the fault model, and evaluates the health state of physical equipment through machine learning and clustering analysis. Based on real-time data of state perception, intelligent reasoning algorithm is used to predict possible fault problems of equipment, so as to maintain before equipment fault, safeguard work safety and reliability of equipment, and reduce maintenance costs and service costs[2]. PHM enables us to carry out equipment safeguard and maintenance activities with pertinence, thus resource use efficiency is maximized. PHM changes the traditional maintenance support mode, realizes the transformation from the traditional breakdown maintenance and regular inspection to condition-based maintenance and on-condition maintenance, and provides the favorable autonomous safeguard system for the entire life cycle of equipment operation.
3. System Framework

In hydraulic engineering, due to complicated environment, it brings a great challenge to maintenance of water conservancy facilities. PHM system uses the advanced detection means to supervise the operation state and health state of facilities in hydraulic engineering, analyzes historical data and real-time monitoring data to judge existence of fault, uses the intelligent algorithm to do fault diagnosis for facilities in the system, predicts future operation and service life of equipment, evaluates health state of equipment, conducts early warning for fault problems, and formulates the maintenance policy for practical health conditions of facilities, so as to safeguard safe operation of water conservancy facilities. Health diagnosis and safe early-warning system of water conservancy facilities based on PHM includes 5 levels[3], as shown in Figure 1.

Data acquisition layer: this layer uses sensors and Internet of Things and combines with artificial inspection to do real-time data acquisition for valves, hoists, control valves, electric generators and transformers, or other water conservancy facilities. Data are considered as the core power for the entire PHM system to drive the system operation, collect geometry, physics, and state information of equipment, and provide foundation for the subsequent data analysis.

Network transmission layer: through wide area network, local area network and field bus or other network transmission technologies, information collected conducts the end-to-end transmission and provides the reliable data transmission services for the upper layer.

Data storage layer: different data collected are classified. The special database is constructed for storage.

Processing analysis layer: Different types of data need different means to analyze. Original data collected can’t be analyzed directly, but data collected should conduct pretreatment to propose feature components in the information. Information collected is extracted to the middle layer for data cleaning, transformation, and integration. Then, data mining and machine learning are used to do scientific analysis for data.

Functional module layer: This layer refers to the functions owned by the health diagnosis and safe early-warning system of water conservancy facilities based on PHM. The fault model is constructed and monitoring data are analyzed reliably, so as to realize fault diagnosis, life prediction and health diagnosis[4].

4. System function

Health diagnosis and safety pre-warning system of water conservancy facilities based on PHM mainly includes seven functions, including data acquisition and pretreatment, fault model construction, condition monitoring, fault diagnosis, life prediction, health evaluation, and maintenance management. The technical system of system functions is shown in Figure 2:
4.1. Data acquisition and pretreatment

Since the entire system is realized by data driving, data acquisition function is extremely important. Without reliable data, it is impossible to conduct analysis and diagnosis. Data acquisition equipment is used to collect temperature, vibration, geometry, mechanical parameters, and operation state for key equipment and parts, including valves, hoists, microcomputer monitor control system, hydraulic parts and electrical equipment. Information collected is transmitted to the computer of the treatment center through the transmission network. Data collected data noise reduction, feature extraction and data standardization for data classification and storage, form the data form required by the subsequent diagnosis and analysis[5].

4.2. Fault model construction

The key technology of fault prediction and health management is to do health diagnosis for equipment through real-time operation situations of equipment. In order to evaluate the health state of equipment, it is necessary to construct the model for evaluation. The fault model is the standard for fault diagnosis and prediction. Good or bad model determines the diagnostic results and predictive accuracy[6]. The key is to solve the fault modeling problem of key parts, components, assemblies and modules of water conservancy facilities, capture the internal relation of data through statistical analysis and algorithm, get mapping model from data to state and study fault mechanism and failure model of parts. Lots of historical data are used to study fault evolution and development law, and lay a foundation on predicting reliable working life of parts.

4.3. Condition monitoring

Condition monitoring realizes all real-time data display of data acquisition and treatment module, provides favorable human-computer interaction interface, and achieves the condition monitoring, fault monitoring, abnormal state analysis, and historical data inquiry of the system. In the human-computer interaction interface, it can realize visualization positioning for the monitoring point, use monitoring data of practical operation state, realizes visualization of abnormal equipment and fault monitoring function, and provides basis for fault diagnosis, health management and formulation of maintenance decision-making of the subsequent equipment[7].

4.4. Fault diagnosis

Fault diagnosis is based on failure model and fault mechanism of water conservancy facilities. By combining with historical data and relevant data, the method based on the model and data is used to do fault diagnosis for the hydraulic equipment parts or systems and predict fault development tendency in the future. Besides, condition monitoring data can be used to diagnose fault, analyze causes for the fault, and accurately locate the fault position, laying a foundation on the subsequent fault isolation and formulation of maintenance strategy[8]. Based on data and fault model sensed by state, machine learning and cluster analysis or other data processing analysis technologies are used to do integrated treatment for information of water conservancy facilities and predict the possible fault problems, fault parts and probability in the future. In addition, threshold is set up. When certain threshold is exceeded,
it will give early warning reminder, providing powerful support for maintenance work of equipment.

4.5. Life prediction
Life prediction of water conservancy facilities is based on the previous analytical diagnosis. Life prediction is based on lots of historical monitoring data, experience base and expert knowledge base. By constructing the life prediction model, the suitable predictive algorithm is allocated to analyze the state degenerative process of facilities. Also, environmental data, operation overhauling data, fulfillment data of facilities are used to predict residual lifetime of equipment\(^{(9)}\). The entire life cycle used by the equipment is supervised. Replacement measures should be taken to equipment to be upgraded, so as to avoid from more losses.

4.6. Health evaluation
Health evaluation of water conservancy facilities constructs the health state evaluation index and system, determines division of health grade and evaluation standards of health state. By combining with fault diagnosis and life prediction results, lots of state sensing data are used to complete a series of packaging algorithm treatment, output evaluation results of facilities’ health state, and provide health management, health state warning, and historical health recording inquiry. Health evaluation results will be stored in the historical database to provide reference basis for the future analysis and diagnosis.

4.7. Maintenance management
Maintenance management of water conservancy facilities based on PHM means that the system uses experience base and expert knowledge base, utilizes machine learning and big data analysis in line with fault diagnosis, life prediction and health evaluation results, proposes the reasonable maintenance planning by combining with fault problems, fault degree and causes found in fault diagnosis, and formulates the suitable maintenance scheme in accordance with fault prediction, life prediction and health evaluation for the equipment\(^{(10)}\). Decision makers can propose a scheme through the system, take more optimal schemes in accordance with physical truth, realize reasonable configuration of resources, and improve maintenance efficiency of facilities.

5. Conclusions
Scientific progress also proposes the higher requirements for equipment reliability, while bringing more convenience. Hydraulic engineering has a direct influence on people’s life. Safe operation of hydraulic engineering is the important problem that we can’t ignore. PHM is used to equipment management of hydraulic engineering, conducts real-time monitoring for water conservancy facilities, conducts fault diagnosis for fault problems, evaluates health state of equipment, and predicts service life of equipment, and formulates the reasonable maintenance strategy by aiming at the physical truth of water conservancy facilities, so as to ensure safe operation of water conservancy facilities.

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References
[1] Song Degang and Niu Qiming, Big Data PHM System Research and Application of High-speed Train[J], Railway Computer Application, 2018, 27(10): 44-48.
[2] Zhang Zhiyong, Operation and Management Exploration of Hydraulic Electromechanical Devices[J], Industry and Technology Forum, 2018, 17(19): 234-235.
[3] Nian Fushun, Cognition on Fault Prediction and Health Management Technology[J], Journal of Instruments and Apparatus, 2018, 39(08): 1-14.
[4] Xu Guangning, Wen Xinxiu and Zeng Ya, the Study and Design for Health Management System of Airborne Equipment Based on PHM[J], Compute Era, 2018(08): 47-50.
[5] Xie Guangyao, Liu Jingquan and Zeng Yuyun, Application and Prospect of PHM in the Nuclear Power Plant[J], Nuclear Power Engineering, 2018, 39(02): 189-192.

[6] Qiu Lijun and Wu Minghui, Overview of PHM Technical Framework and Key Technology[J], Overseas Electronic Measurement Technology, 2018, 37(02): 10-15.

[7] Wang Linqui, Zheng Lei and Zhang Yongwu, the Study on the Health Management Technology of Complicated Electromechanical System Based on PHM[J], Computer Measurement and Control, 2018, 26(01): 27-30.

[8] Pan Yongjie, Zhao Xinxin, Liu Xiaoguang, Wei Qiankun, and Lu Yongqiang, the Key Technical Study and Application of Long-span Bridge PHM System Based on BIM[J], Railway Architecture, 2018, 58(01): 5-9+19.

[9] Li Guoping, Fault Diagnosis of Raw Water Delivery Pump Equipment and Health Analysis Evaluation System[J], Water Purification Technology, 2017, 36(06): 100-106.

[10] Li Yongliang, the Study on PHM Based on Machine Learning[D], University of Electronic Science and Technology of China, 2017.