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Condition-Based Maintenance Decision-making Support System (DSS) of Hydropower Plant

Irfan Jamil[1], Rehan Jamil[2], Zhao Jinquan[1], Li Ming[2], Wei Ying Dong[3], and Rizwan Jamil[4]

[1]College Energy & Electrical of Engineering,
Hohai University, Nanjing, China

[2]School of Physics & Electronic Information,
Yunnan Normal University,
Kunming, Yunnan Province, China

[3]Department of Electrical Engineering,
Tsinghua University, Beijing, China

[4]Heavy Mechanical Complex (HMC-3),
Taxila, Rawalpindi, Pakistan

ABSTRACT: Condition-based maintenance is a kind of maintenance which conducted before fault by judging device exception and predicting device fault based on device condition information provided through monitoring device condition. The analysis result of fault diagnosis technology and production management information system which has namely arranged the maintenance plan. The implement device maintenance in light of device health condition due to prevents excessive maintenance or disrepair of device to the utmost extent. During operation, primary device of hydropower plant constantly suffers from sand abrasion, cavitation damage, mechanical wear and other mechanical or electrical damage, which reduces the efficiency of generating equipment and shortens the service life. If timely monitoring and diagnosis and appropriate maintenance are not provided, accident may be induced and cause great economic losses; to make primary devices for production and transmission of electric energy of hydropower plant have high reliability and be in good operating conditions, such primary devices must be maintained. The aim of this paper is to define the gradually improving sensor and monitoring technology which offer the possibility of condition-based maintenance of hydroelectric generating unit and the extraction and analysis methods of fault characteristics. Therefore discussion is summarized briefly on composition, configuration and functions of Condition-based Maintenance System (DSS). And also describes the short introduction of Condition-based Maintenance (DSS) system in typically project of Songjianghe Hydropower Plant as used for primary devices.

KEYWORDS: Condition-based maintenance, DSS, Monitoring device, fault diagnosis, Primer device, Hydropower Plant.

1 INTRODUCTION

The Condition-based maintenance is a maintenance technique that involves monitoring machine condition and predicting machine failure [1]. Generally these systems are controlled by computers. Device maintenance mode has two modes, Break-down maintenance mode and planning maintenance mode. Break-down maintenance which refers to the maintenance conducted after device fault. And at that time, the fault has occurred and loss has been induced. In planning maintenance mode, it refers to the maintenance conducted based on the artificially prescribed maintenance cycle.

Corresponding Author: Irfan Jamil (irfan.edu.cn@gmail.com)

It is obvious that “excessive maintenance” and “insufficient maintenance” will necessarily happen in case devices under different conditions are maintained based on the unified cycle. So the planning maintenance cannot give full play to the potency of the devices and shall waste a large number of financial and human resources, and the fault cannot be found in time, which shall not only cause economic losses and waste of human resources but also may induce disastrous accident. The condition-based maintenance is conducted before fault by judging device exception and predicting device fault based on device condition information provided through condition monitoring device, analysis result of fault diagnosis technology and production management information system, namely, arrange the maintenance plan and implement device maintenance in light of device health condition and prevent excessive maintenance or disrepair of device to the utmost extent.

Evaluate the device condition in real time to grasp current operating condition of the device, timely eliminate the hidden risk of device with defect, improve device serviceability rate and health level, ensure safe operation of the device; for devices in favorable operation, properly extend maintenance cycle, reduce waste of human resources and material and avoid excessive maintenance of device. Carrying out the reasonable device maintenance strategy and reasonably applying condition-based maintenance management mode are of great significance in improving device reliability, reducing device maintenance cost and extending asset life cycle [2]. Reduce planning maintenance, avoid break-down maintenance, develop condition-based maintenance and promote optimal maintenance are device maintenance guidelines. The fig.1 shows composition of Proportions of the Optimal Maintenance Model as per maintenance guidelines.

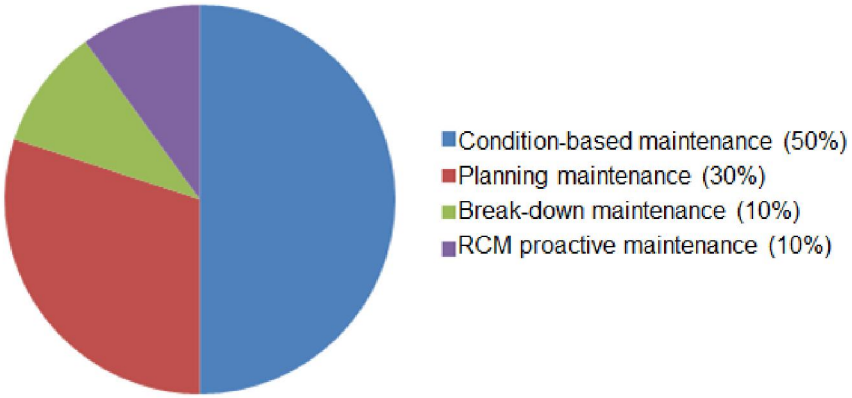

Fig. 1. Composition of Proportions of the Optimal Maintenance Model

Development course of condition-based maintenance: The evolution of device maintenance system reflects productivity development level and technology management level and the appropriate maintenance mode should be adopted along with advancement of theoretical and technological levels. The evolution of device maintenance system reflects productivity development level and technology management level and the appropriate maintenance mode should be adopted along with advancement of theoretical and technological levels. Currently the gradually improved sensor and monitoring technology offer the possibility of condition-based maintenance of hydroelectric generating unit and the extraction and analysis methods of fault characteristics are also improved, but objectively speaking, there is no hydropower station where condition-based maintenance is realized in its true sense in China.

Technological orientation of condition-based maintenance: To establish a unified maintenance information platform for condition monitoring of hydropower plant to realize acquisition of condition data, feature calculation, real-time monitoring, fault record, performance test record and technical diagnosis of hydropower generating primary devices like generator, hydraulic turbine and transformer, offer unified data access model and analysis and diagnosis model for different devices and provide technical assurance for transition from planning maintenance to condition-based maintenance of hydropower plant, thus promoting the realization of condition-based maintenance. Based on device reliability maintenance technology, borrow ideas from asset management thought of device whole lifecycle and adopt the method that conforms to the international network communication standard IEC61850-MMS to carry out data transmission and sharing and establish a unified maintenance information platform for device condition monitoring of hydropower plant.

Implement method that adopts condition-based maintenance assistant decision-making mode, construct subject data center of device condition, apply diagnosis and analysis system, reliability maintenance strategy and other advanced application algorithm and model to realize condition evaluation, fault diagnosis and condition forecast of the devices.

2 CONSTRUCTION COMPOSITION OF CONDITION-BASED MAINTENANCE SYSTEM

Composition of condition-based maintenance technical system has Unit vibration/swing protection system, Monitoring system of circuit breaker and transformer, Condition monitoring and tendency analysis system of hydropower plant, Computer supervisory monitor system, Production management system and Condition-based maintenance decision-making support system (DSS).

Establish a unified maintenance information platform for device condition monitoring of hydropower plant, acquire relevant basic data of the generator, hydraulic turbine, transformer, circuit breaker and other primary devices of hydropower plant, real-time/historical data of the devices and other characteristic parameters that reflect device health condition and evaluate current health condition of the devices, carry out effective risk evaluation, finally implement comprehensive analysis, reasoning and diagnosis through the optimal maintenance strategy model, give maintenance suggestions, and transmit the analysis conclusions and maintenance suggestions to production information management system through service bus to facilitate the inquiry and reference, thus providing technical assurance for the transition from planning maintenance to condition-based maintenance of hydropower plant to effectively support the specific implementation of condition-based maintenance work [3].

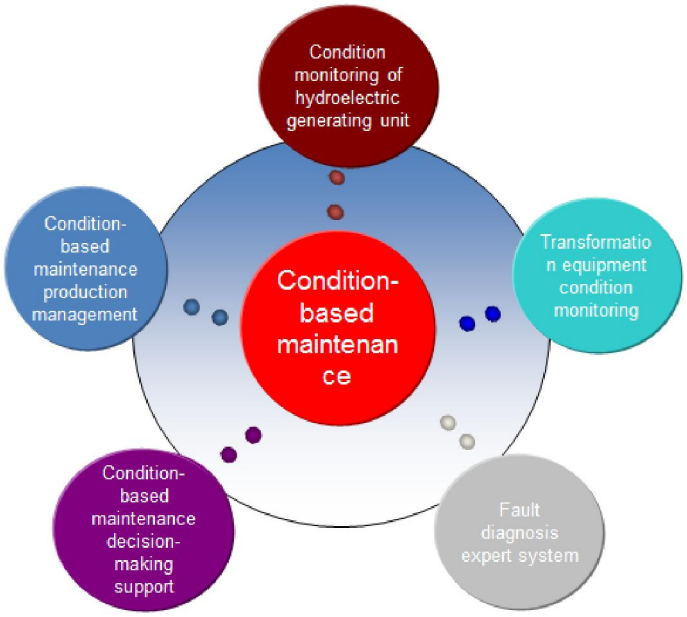

Fig. 2. Maintenance information platform for device condition monitoring of hydropower plant

3 CONFIGURATION OF CONDITION-BASED MAINTENANCE DSS

3.1 HARDWARE COMPOSITION

Plant station access server: service for access to data acquired and analyzed by condition monitoring equipment of each station, Real-time plant station database server: service for storage and inquiry of the original 72h "black box" data of condition monitoring equipment of each station, Centralized control monitoring data server: service for storage and inquiry of condition monitoring access data of equipment of the whole plant, Centralized control maintenance application server: service for operation access application of condition-based maintenance assistance decision-making of equipment of the whole plant, Mobile engineer work station (EWS): system equipment model definition, user permission management and database maintenance service, Network auxiliary equipment: safe networking service, System software function framework: Data acquisition, Data processing , Monitoring & early warning , State analysis, State diagnosis, State evaluation, Forecast evaluation, Risk assessment, Making suggestions for decision.

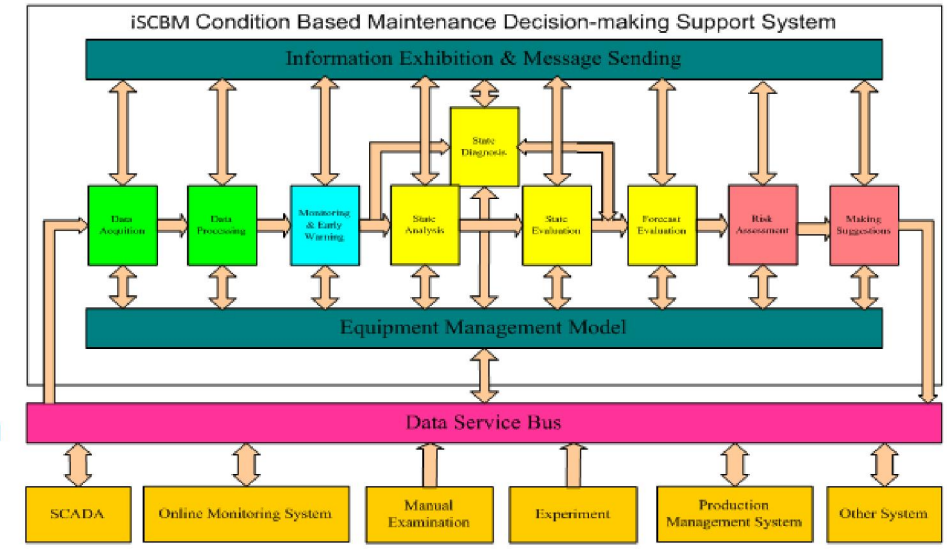

Fig. 3. Diagram of Software Functions of Condition-based Maintenance Decision-making Support System

4 FUNCTIONS OF CONDITION-BASED MAINTENANCE DSS

Data acquisition module: Analyze object model of hydropower generating primary device, and effectively acquire from external system or device various basic equipment data, real-time data, inspection and test data and other data that reflect equipment health condition to provide data resources for further judgment and evaluation.

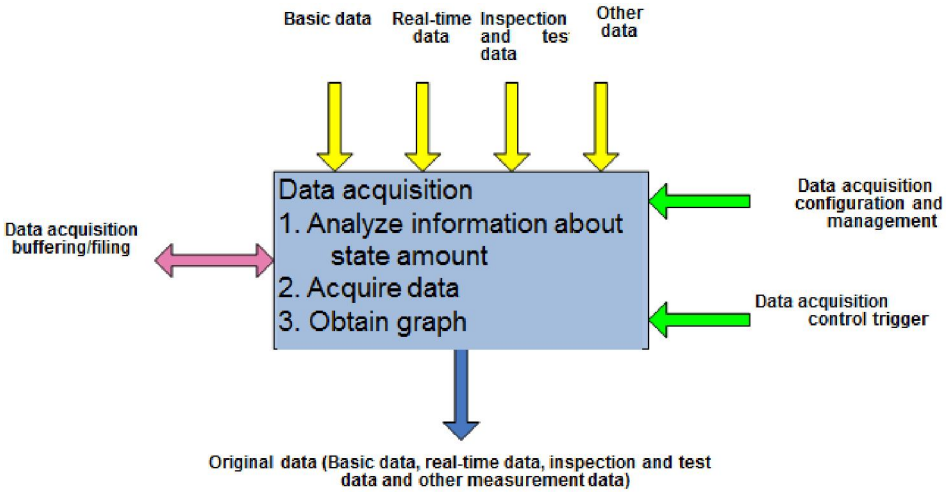

Fig. 4. Data acquisition module

Data processing module: Process the data based on the acquired data resources in light of business demand and extract the data concerning amount of state the reflect current operation performance of the equipment for monitoring & early warning and state evaluation.

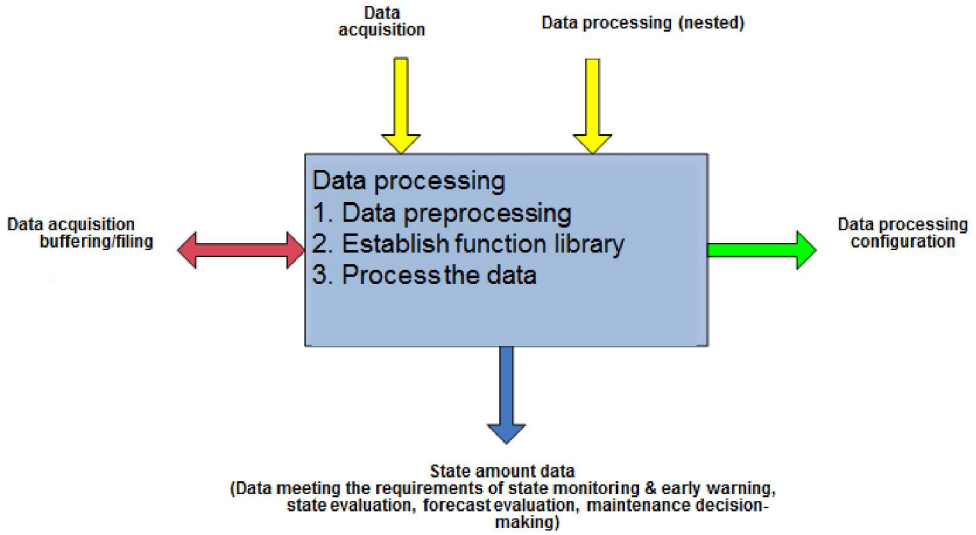

Fig. 5. Data processing module

Monitoring & early warning module: Monitor the change of state amount index, give early warning for equipment state amount going beyond the scope specified by state evaluation guidelines and regulations and timely release early warning information to equipment management personnel at all levels based on the various categories and levels.

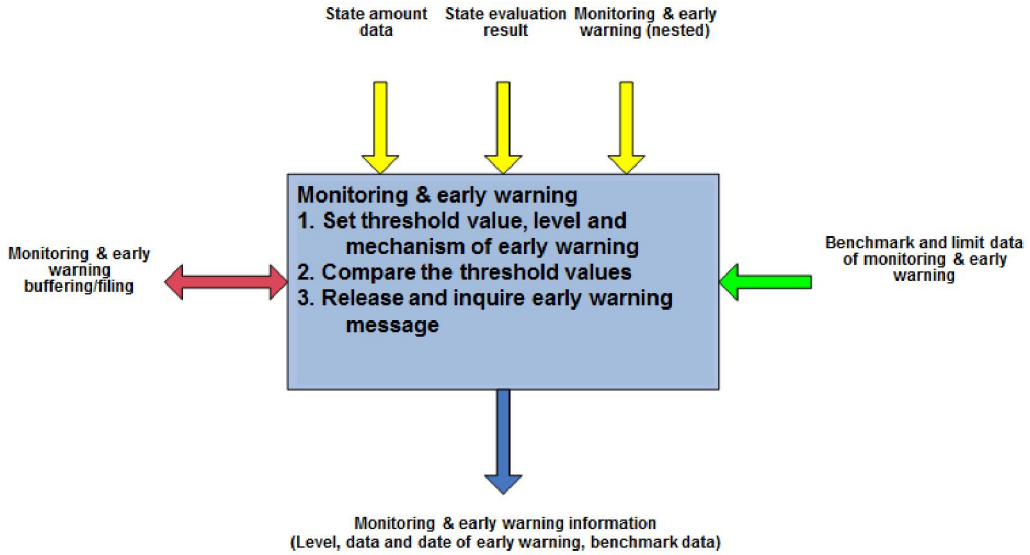

Fig. 6. Monitoring & early warning module

State Analysis module: Adopt various state analysis methods (time-domain analysis, frequency-domain analysis, correlation analysis, wavelet analysis, tendency analysis, transient analysis, characteristic spectrogram analysis, etc.) to analyze current operating condition and health level of the equipment/component. And you may integrate state analysis function of condition monitoring system and historical tendency analysis function of tendency analysis system.

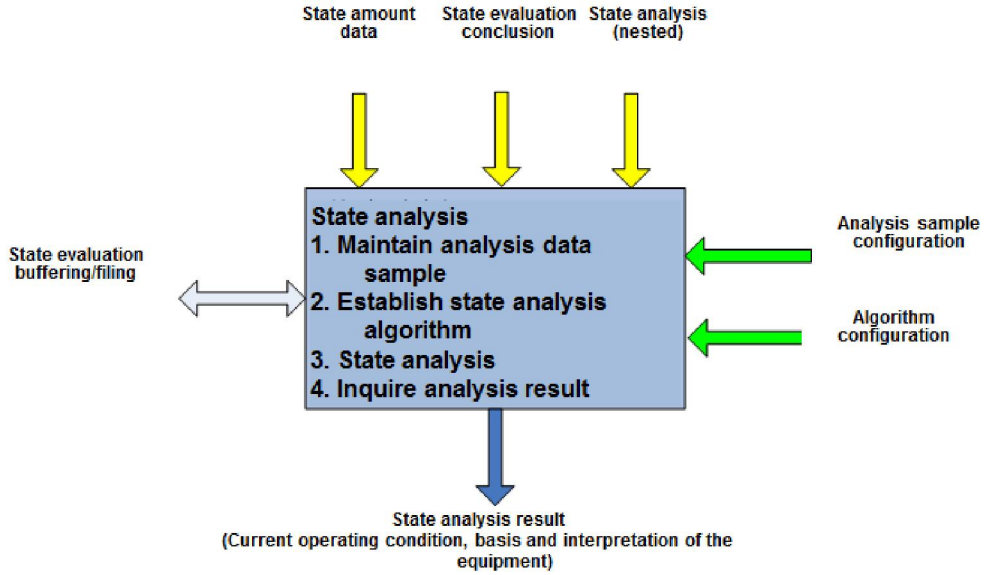

Fig. 7. State Analysis module

State diagnosis module: For equipment with state amount index going beyond the early warning or that with descending health level, adopt state diagnosis method to diagnose the cause and position of possible fault of the equipment and guide fault handling and state recovery.

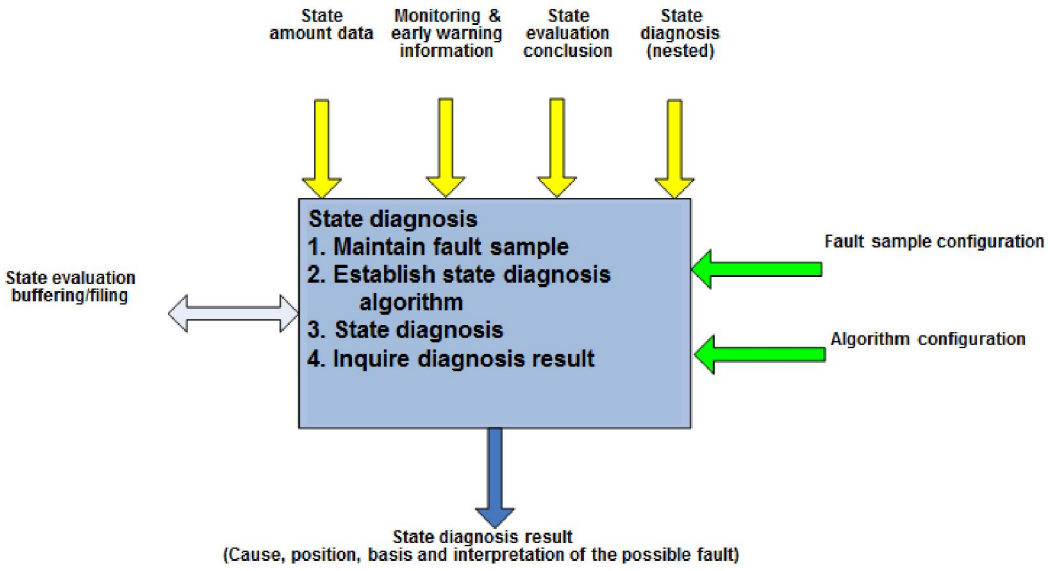

Fig. 8. State diagnosis module

State evaluation module: Analyze and evaluate date concerning all state amount indexes that reflect equipment health condition in accordance with state characteristic quantity and state evaluation guidelines and standards for primary devices of hydropower plant.

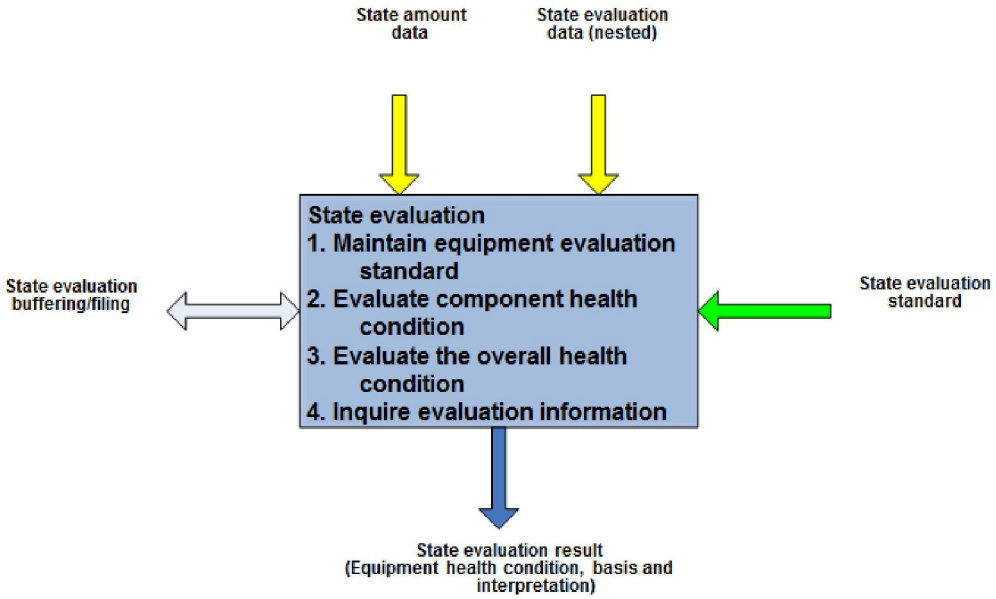

Fig. 9. State evaluation module

State forecast module: Use current and historical state data of the equipment and adopt appropriate forecast algorithm to diagnose and evaluate the state development tendency of the equipment in a future period

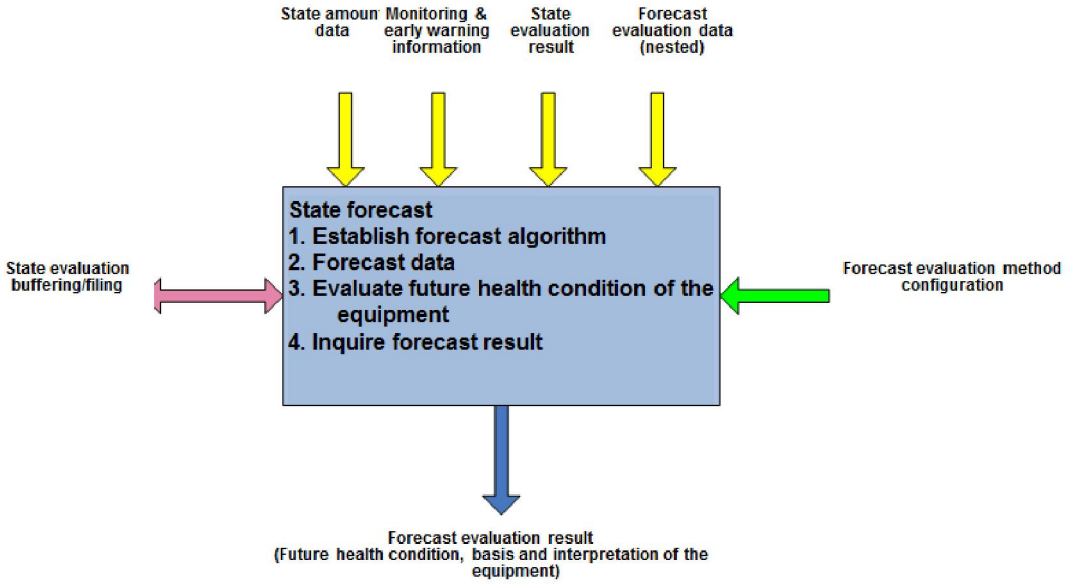

Fig. 10. State forecast module

Risk assessment module: Analyze asset loss degree in case of equipment failure threat and the probability of such threat by identifying the potential internal defect and external threat of the equipment, and obtain equipment risk level through risk assessment algorithm.

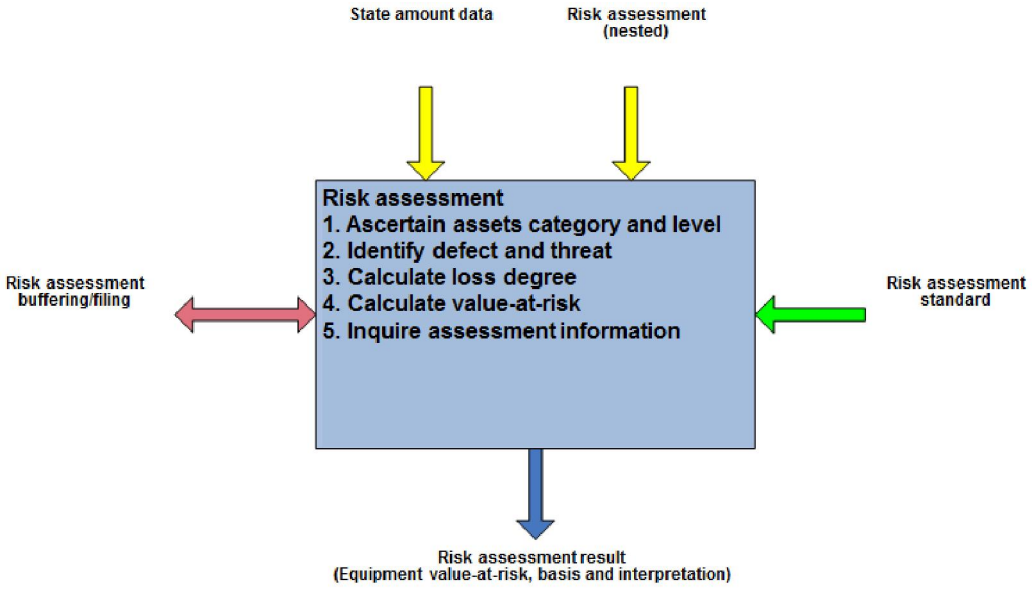

Fig. 11. Risk assessment module

Decision suggestion module: Take equipment state evaluation result as the basis, take account of risk assessment conclusion, optimize maintenance sequence, maintenance time and maintenance grade arrangement of primary devices for hydropower generation, and submit the suggested results to equipment management personnel or deliver them to related external production management system.

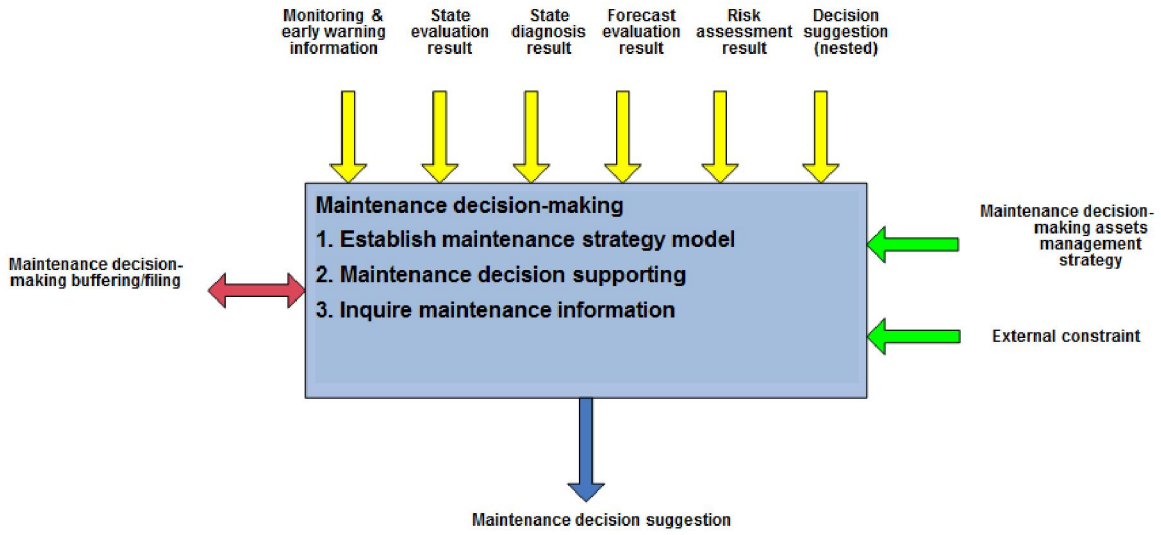

Fig. 12. Decision suggestion module

4.1 KEY TECHNOLOGIES TO THE SYSTEM

In fault diagnosis system, There are three intelligent diagnosis methods, namely, expert system approach, fault tree analysis (FTA) and case-based diagnosis method, shall be adopted for system fault diagnosis at the same time, and multi-information fusion technology based on D-S evidence theory (Dumpster/Shafer evidence theory) shall be used to integrate the three kinds of diagnosis results and obtain a final diagnosis result.

4.2 SYSTEM TECHNOLOGICAL CHARACTERISTICS

Introducing hydraulic turbine, generator equipment type, equipment component and equipment parameter modeling system into online monitoring and condition-based maintenance assistant decision-making support conforms to

development idea of equipment condition-based maintenance. Based on B/S mode and service-oriented architecture (SOA) distributed "online monitoring and condition-based maintenance assistant decision-making system of primary devices for hydropower generation", set up a unified platform for condition monitoring, fault diagnosis and maintenance decision-making of primary devices of hydropower plant; Introduce the technology for monitoring, analysis and diagnosis of conditions like vibration, swing, pressure fluctuation, air gap, magnetic flux, partial discharge, energy efficiency, operating condition, transformer oil chromatography, the technology for information interconnection and sharing of the unified platform and production management system and the standard data communication technology of IEC61850 intelligent substation, to provide the complete signal sample acquisition, multi-dimensional tendency analysis, in-depth data mining, comprehensive decision-making supporting and other technical means for setting up online monitoring and condition-based maintenance decision-making support platform.

Provide the data concerning the actual vibration region of the unit to the monitoring system, guide the automatic generation control (AGC) to keep away from the actual vibration region of the unit for operating so as to truly improve unit operating efficiency and extend unit service life; Based on the application of real-time database, provide the favorable solutions for organization, compression, transmission, storage, management and retrieval of mass data of equipment condition monitoring and maintenance system of hydropower plant; Applying three-dimensional digital modeling technology in model view building and dynamic demonstration of hydraulic turbine, generator and other primary devices and components of hydropower plant conforms to friendly and interactive development direction of current condition-based maintenance system

5 TYPICAL APPLICATIONS OF CONDITION-BASED MAINTENANCE DSS

PROJECT PROFILE

Songjianghe Hydropower Plant was established in August 1997 and lies in Fusong County of Jilin Province, China. The entire project is composed of three power stations (Xiaoshan Power Station, Shuanggou Power Station and Shilong Power Station) and two diversion projects (respectively in Songshan and Sandao Songjianghe), with the design total installed capacity of 510MW and average annual energy output of 836,900,000KWH. Decision support system (DSS) introduces technology, and presents a function & composition of multiage based maintenance decision support system used for Songjianghe Hydropower Plant equipment today [5].

Fig. 13. online monitoring and condition-based DSS information platform of Songjianghe Hydropower Plant

We studied previously some decision support systems (DSS) to maintain the equipment in hydropower plant [5]. In Songjianghe Hydropower Plant monitoring parameters are set up online monitoring and condition-based DSS information platform to realize state monitoring, state evaluation, fault diagnosis, state forecast and maintenance decision-making for 6 hydraulic turbines, generators, transformers, circuit breakers and other primary devices of the whole plant, thus making equipment health records.

6 CONCLUSION

This paper actually provides an introduction to the maintenance profession and studies various approaches to the practice of Condition-Based Maintenance Decision-making Support System (DSS). Condition-based maintenance Decision-making Support System (DSS) is a primary device of hydropower plant which requires maintaining in monitoring machine

condition and predicting machine failure. With the maintenance systematic plan strategy and reasonably applying condition-based maintenance management mode are of great significance in improving device reliability, reducing device maintenance cost and extending asset life cycle in hydropower plant.

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