The Design and Realization of Remote Monitoring and Diagnosis & Prediction System for Large Rotating Machinery

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Abstract: The performance and complexity of large rotating machinery rising the traditional on site fault diagnosis means have been unable to meet the needs. The remote monitoring and diagnosis technology is a new fault diagnosis mode combined the computer technology, communication technology and fault diagnosis technology. The designed remote monitoring and diagnosis & prediction system for large rotating machinery integrates the distributed resources in different places, breaks through shortcomings as the off-line and decentralized information, makes further implement of equipment prediction technology research on the basis of condition monitoring and fault diagnosis, provides on-site analysis results and carry out online actual verification of the results. Remote monitoring and diagnosis & prediction system monitors the real-time condition of the equipment and achieve early fault prediction with great significance to guarantee the safe operation, save maintenance costs, improve utilization and management of the equipment.

Key words: large rotating machinery, remote monitoring, fault diagnosis, prediction system

1 Introduction

The maximization, automatization, high-precision, high efficiency and electromechanical integration development tendency of equipments have created the conditions for enterprises to improve production efficiency. However, the increasing performance and complexity of equipment and the high correlation among components have led a series of problems, including frequent paroxysmal failure of machinery, high downtime losses and maintenance expense and long maintenance cycle.

Condition monitoring and fault diagnosis systems now mainly work in following modes: 1) offline condition monitoring and fault analysis mode; 2) single equipment online condition monitoring and fault analysis mode; and 3) centralized online condition monitoring and fault analysis mode. In offline condition monitoring and fault analysis mode, the operation information of sensor pickup unit is detected and inputted to the computer through data acquisition device, and then the computer carries out analysis and diagnosis. This mode is economic and convenient but is only applicable to regular detection. In single equipment online condition monitoring and fault analysis mode, a set of condition monitoring and fault analysis system is installed for each of the equipment. This mode enjoys advantages such as good real-time performance and high reliability, but it is not economic and it is hard to share information among monitoring and diagnosis systems. Although bad economic performance and information sharing difficulty are overcome, centralized online condition monitoring and fault analysis mode is limited by territorial restriction and fails to carry out remote diagnosis.

Industrial Ethernet-based remote monitoring and fault diagnosis technology has become the research focus at home and abroad with the development of Internet. Breaking through the framework of the original monitoring and fault diagnosis concept, the openness of remote monitoring and diagnosis technology improves the monitoring and fault diagnosis technology against equipment. After the remote monitoring, diagnosis and forecasting system of large-scale rotating machinery is established, the vibration and process parameters of large-scale rotating machinery is obtained online during operation and transmitted to the data center of remote fault diagnosis for automatic storage, where data which is valuable for diagnosis is analyzed and professional diagnosis atlas is provided so that experts who provide diagnosis services for enterprises can know the operation state of unit “at any time in any place” even he/she is thousands of miles far away, existing diagnosis service mode which is focused on “afterwards service and onsite service” is broken, passive service is replaced by active service, unit fault is alarmed in early stage and remote expert consultation is realized and accurate judgment is made for fault reason, degree and development tendency by detecting the early sign of fault; thus it is ensured that the production enterprise prepares maintenance parts and arranges maintenance plan in time to eliminate unnecessary economic losses and declined equipment performance resulting from regular maintenance, avoids blind maintenance, eliminate potential failures in early stage, enhances the reliability of equipment and minimizes maintenance cost.

2 Construction of Remote Monitoring, Diagnosis and Forecasting system for Large-scale Rotating Machinery

Most of large and medium-size sate-owned enterprises with large-scale equipment are reorganized and emerged into groups. Each group is comprised by a number of subordinate businesses, especially in petrochemical, water conservancy and electrical fields. Equipments of these groups are similar to each other and it tends to find out similarity during management. By the popularization of remote monitoring and diagnosis technology, group headquarters may carry out convenient remote management and monitoring against onsite equipments of subordinate businesses, manage the operation data of subordinate businesses uniformly and conduct real-time monitor and data statistics for each unit. These are helpful for group companies to strengthen unified management and maintenance guidance against onsite equipments and popularize and implement state maintenance and are beneficial for information sharing and experience exchange among subordinate businesses.

2.1 General design of remote monitoring and forecasting system for large-scale rotating machinery

The structure model of remote monitoring, diagnosis and forecasting system based on existing development technologies is shown as figure 1, with this system, the remote diagnosis, service and management against units are truly realized.

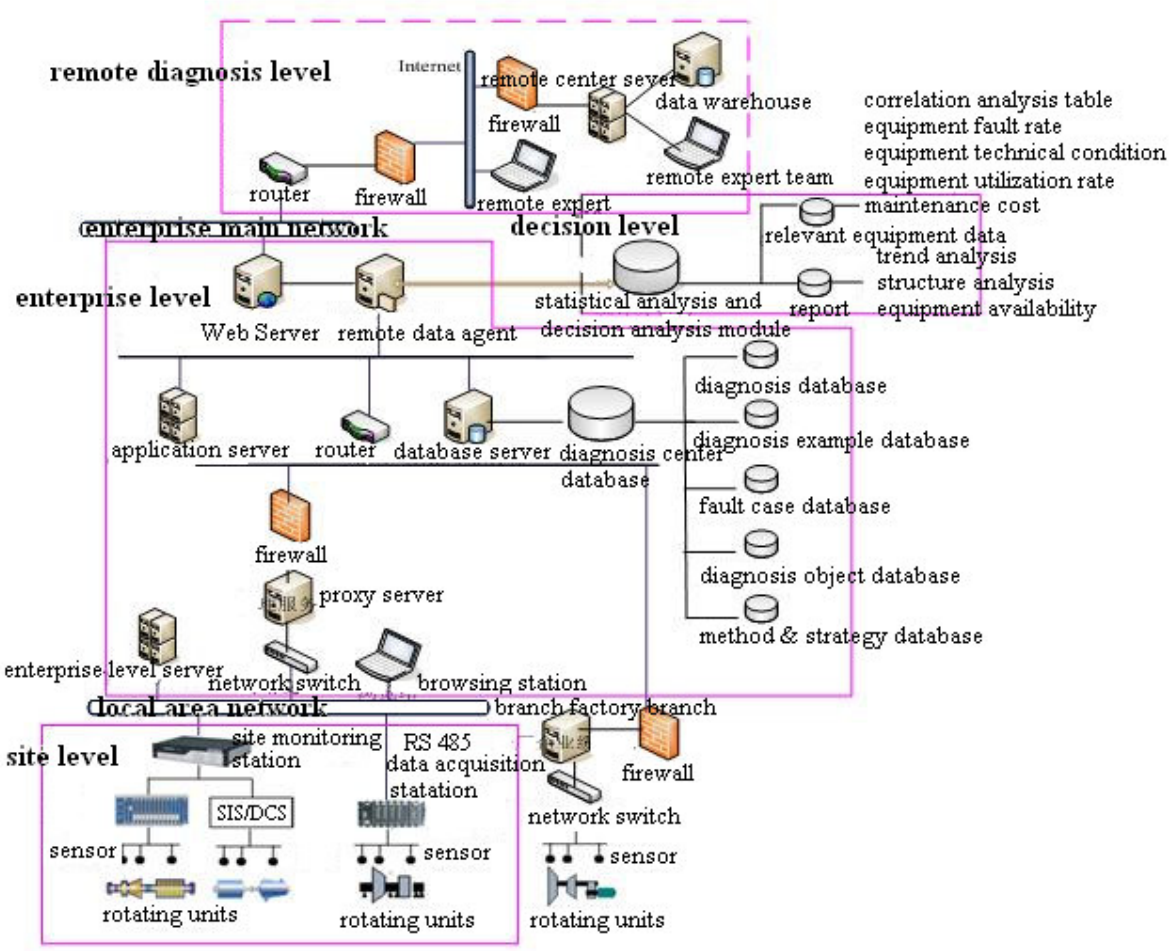

Figure 1 Structure of Remote Online Monitoring Diagnosis and Forecasting system of Large-scale Rotating Machinery

Without changing the original front end acquisition system, this system remotely acquires the real-time and historical operation state information of the unit through Internet and full Web and constitutes a convenient and practical remote monitoring and forecast interactive platform. This system supports both online monitoring system and general offline monitoring system, i.e. analysis and diagnosis is still available with the analysis method provided by this system when the data is saved as the client-end .txt file.

According to the aforesaid figure, the model is divided into 4 levels, namely, onsite level, enterprise level, remote diagnosis level and decision-making level, users of different levels may handle different services according to their demands:

1) On-site level: is mainly for data acquisition,

real-time signal treatment and conventional diagnosis.

2) Enterprise level: connects the client computer to server and coordinates remote requests among client computers, application servers and database servers.

3) Remote diagnosis level: its remote end consists of remote expert team, individual remote expert and data warehouse, etc.

4) Decision-makeing level: it is actually an output module which provides reference data for Enterprise Apparatus Management (EAM) so that enables the enterprise realize system integration.

Of these levels, original acquisition task and basic signal treatment as well as conventional diagnosis are completed in on-site level; in enterprise level, the existing experts and expert system of the enterprise are employed to carry out diagnosis and forecast against difficult troubles within the Intranet, and the diagnosis center database is established and improved by learning, and cases and methods & strategies are enriched; meanwhile the needed remote information is arranged by the remote data agent and transmitted to remote client end; in remote diagnosis level, data warehouse and diagnosis expert situated in different places are employed to solve faults, to which, enterprise level experts fail to conduct judgment and provide constructive suggestions; while decision-making level for whether to conduct maintenance, purchase, etc. shall be made according to the monitoring data and statistics report forms which are relating to equipment and acquired by the enterprise in decision-making level.

2.2 Design of remote monitoring system

Remote-based fault diagnosis system adopts C/S or B/S system structure, and either the monitoring and acquisition system on the equipment site or the diagnosis system of remote diagnosis center may serve as the server, in another word, the remote diagnosis center serves as the client computer in case on-site monitoring and acquisition system of the equipment serves as the server, and staffs of the remote diagnosis center download equipment state information data from the network; or the monitoring and acquisition system on the equipment site serves as the client computer in case the remote diagnosis center serves as the server, and staffs on the equipment site upload the equipment state information data. No matter which mode is applied, the diagnosis center will carry out analysis and diagnosis after receiving the data and feed the result back to the site.

Being connected with Windows platform and TCP network protocol, C/S system structure transmits the information data of on-site equipment after compressing or realizes remote control and information exchange with Web technology. Developed from C/S, B/S is a kind of advanced network distributed data management mode, which is comprised by browser, Web server and data management server. Compared with C/S mode, B/S mode not only simplifies the sophisticated development of traditional system but also separates development environment from application environment to facilitate system extension, maintenance and management; the open and distributed application based on Internet easily and efficiently satisfies the demand of remote users in different places, facilitates the integration of other functional systems of the LAN as well as the flexible extension of user functions and improves the efficiency of remote diagnosis. In view of the aforesaid conditions and considering of the application characteristics and real-time requirement of monitoring and fault diagnosis system for large-scale rotating unit, B/S mode and C/S mixed mode is adopted. Combining the advantages of C/S mode and B/S mode, C/S and B/S mixed mode feature the high interaction and safety of CS and client-end platform independence of B/S; see figure 2 for the specific structure.

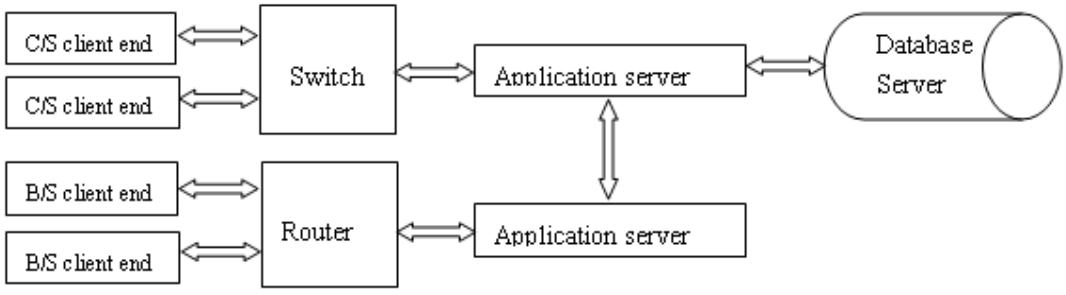

Figure 2 Three-layer Mixed C/S and B/S Structure Application System

In this structure system, B/S structure is adopted by some functional interfaces (for example, information publishing and query interface) which shall be handled with WEB to satisfy requests of most visitors; while C/S structure is adopted by backstage functional applications (for example database management and maintenance interface) which is only used by a few of personnel.

2.3 System functional module

Remote online monitoring and forecasting system of large-scale rotating machinery takes WEB-based remote monitoring technology and large-scale data warehouse as its technology basis, and provides the

remote management platform, remote diagnosis and maintenance platform and remote information communication and exchange platform for the unit. Based on these platforms, enterprises may carry out further constructing and developing more effective and scientific unit management, diagnosis or after sales management system. Functions of this system are divided into five modules:

(1) Remote Data Control: it builds a historical data warehouse for operation information in the headquarter of enterprise. Taking the use of Internet, it transmits the real-time unit operation data, which is acquired by data terminal equipments at each end-user, including diagnosis analysis, forecasting unit key-phase, frequency spectrum of vibration waveform, shaft displacement and eigenvalue of fault frequency and unit process parameters (temperature, pressure, flow, etc.) to the data warehouse of remote center. And unified data management is realized by the warehouse.

(2) Remote Monitoring and Diagnosis: as a website which publishes information on Internet, the remote monitoring and forecasting center shall ensure "delivering proper information to appropriate personnel". The Web browsing mode based-on B/S technology ensures that equipment management and diagnosis & maintenance personnel obtain "real-time" unit management information and operation state data "at any time, in any place" only by visiting the website of remote monitoring center without the installation of special software on personal computer.

(3) Fault Diagnosis and Forecasting Function: in accordance with the demands on fault diagnosis and management from equipment diagnosis service providers, the remote service center provides various professional diagnosis atlases, establishes fault diagnosis case database and furnishes a number of equipment management, exchange and learning functions. The Diagnosis Help Analysis Function can diagnose a great number of common faults, for example, rotor unbalance, misaligned rotor, rotor rub-impact, oil film oscillation, shaft bending, steam flow excited vibration, loosened bearing bush, disconnected parts, parts wear and damage, and NG lubrication etc.

By sharing the data of the remote service center, diagnosis experts can carry out real remote online consultation through network. This function will greatly facilitate the communion between experts, the full use of the scarce resource - "diagnosis expert" and the establishment of Diagnosis Expert Alliance based on the remote center so that provides powerful measures for unit diagnosis and maintenance. Functions of Expert Remote Online Consultation mainly include: online sharing of equipment operation data; co-browsing and sharing of equipment fault analysis atlas; text communication between experts; public WordPad for experts; sharing of experts' files; and transmission of experts' voice and image.

Based on the practical operation data of different units, the Fault Diagnosis Case Database is expanded continuously with diagnosis cases encountered by site users and remote experts during actual work, collections and arrangement conducted regularly by staffs of the remote diagnosis center and the deep processing of data through the remote monitoring and forecasting center. Thus, the aforesaid database will become the common precious resource for fault diagnosis personnel within the industry along with the continuous enrichment and improvement.

(4) Data Statistics and Analysis: it conducts comprehensive analysis and "deep-processing" against the onsite operation data of the unit and provides analysis methods such as automatic collecting electronic report and comprehensive analysis of unit operation so that provides timely, accurate and intelligent analysis data and management methods for group companies or managers of each links of equipment diagnosis service provider as well as designers and diagnosis experts;

(5) General Network Function: furthermore, the system also provides common functions of general websites, including online declaration of equipment management & operation state, information publication, downloading of fault diagnosis paper, user discussion and communication and remote training and learning, to fully satisfy the demand of end users on remote management for equipment, remote discussion and communication and remote training and learning as well as realize the enterprise – user and user – user communication and exchange.

2.4 System functional module

Fault prediction is the key technology to guarantee the long-term safety and high efficient operation of equipment, commonly adopting characteristics parameters tracking methods, that is to infer the value of the characteristics in future on basis of the monitored parameters and to determine the probability of fault generation. The equipment condition trend prediction technology is implemented on the basis of condition monitoring and fault diagnosis to explore fault prediction methods and make further study on the key fault prediction technology. The prediction system is indicated in figure 3.

The data of prediction system is from the actual monitored data provided by the monitoring and diagnosis center. The prediction method is chosen according to the actual data of the actual system combined with equipment characteristics and operating condition and the prediction model is constructed to extract characteristics reflecting equipment condition and track the characteristic

parameters to make prediction. The analysis results are transmitted to the industrial scene to make online verification of the prediction technology and correct and perfect the prediction system. This way accords with the practical situation and easy to get better prediction results.

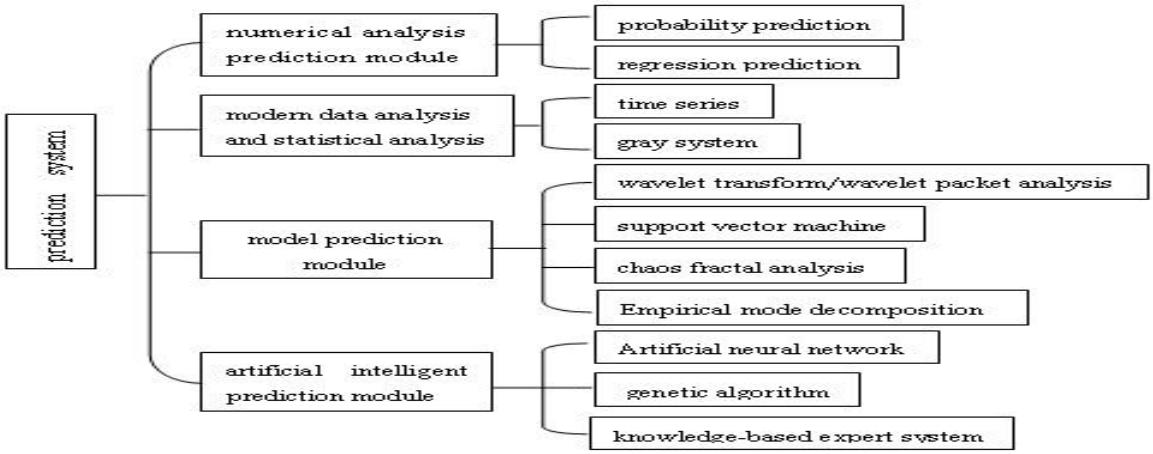

Figure 3 The prediction system

3. System Realization

The scheme of remote monitoring and forecasting system for flue gas turbine is implemented and the remote monitoring and diagnosis center is set up with the aforesaid model of remote online monitoring, diagnosis and forecasting system of large-scale rotating machinery according to characteristics of the catalytic gas turbine unit of a large-size enterprise.

The monitoring system installed for the flue gas turbine contains following functions: monitoring of shaft vibration and displacement, shaft speed and bearing bush temperature, these are monitors against the flue gas turbine; monitoring of wheel disc temperature, inlet oil pressure of front and rear bearings, inlet oil temperature and oil-discharge temperature and backwater temperature of bearing, these are monitors against supporting pipelines of the flue gas turbine; in addition, there is monitoring system for local instrument panel which matches with the flue gas turbine. The monitoring page for the unit outline diagram, which displays the physical formation of the unit directly, is indicated by figure 4.

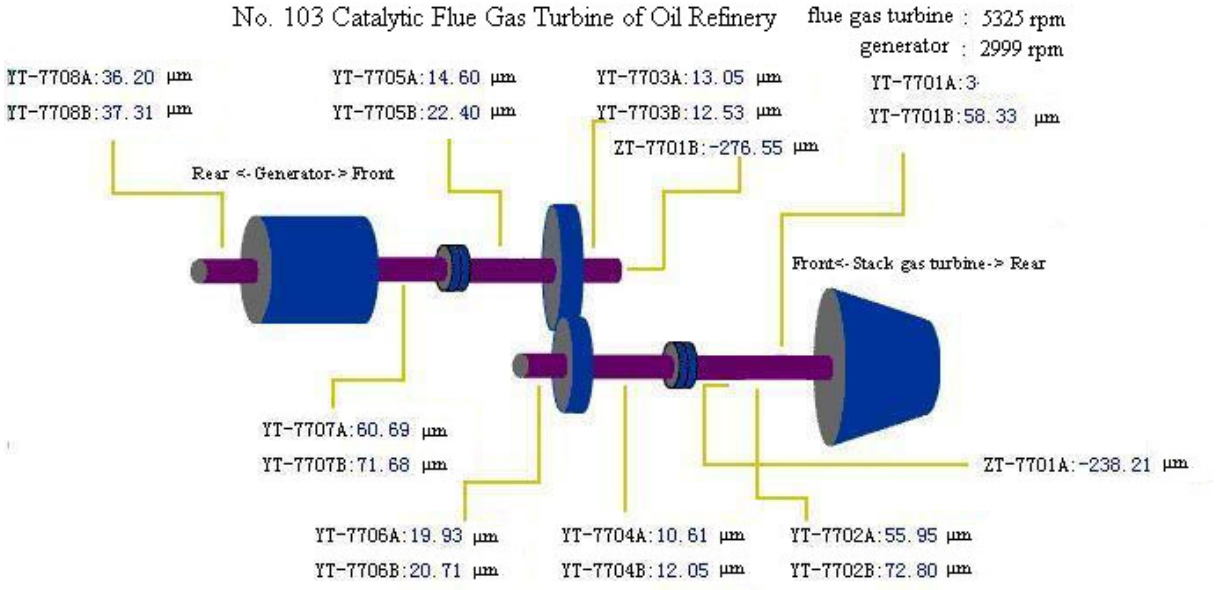

Figure 4 Unit Outline Diagram

With large-scale and hi-fi data compressed technology, the monitoring system transmits a set of data per second to the remote monitoring center, including all original data of each measuring point of the unit, such as waveform, frequency spectrum and process parameter. Any data to be extracted may be handled with the vibration monitoring and forecasting analysis software being developed, value analysis prediction method, time sequence forecasting method, statistics forecasting analysis method and artificial

intelligent-based forecasting method may be applied for analysis, and the forecasting result may be displayed in graph or text.

4. Conclusion

Based on computer, fault diagnosis, network and database technologies, the monitoring, diagnosis and forecasting system of large-scale rotating machinery detects the vibration and process parameters during the operation of the equipment and transmits such data to the remote center through network, enables higher-level management, remote diagnosis experts and onsite operators grasp the operation state of the equipment comprehensively and carry out research on equipment forecasting technology, and is available for prolonging and accumulating maintenance cycle, saving maintenance expense and improving the production and economic efficiency of enterprises on the premise of protecting equipment against major accidents.

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