Research Article

Remote Vibration Monitoring and Fault Diagnosis System of Synchronous Motor Based on Internet of Things Technology

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With the rapid growth of the country's economy and the rapid expansion of the industrial scale, the engine is developing towards high speed, high efficiency, and high power density. Synchronous motors are an important part of the power provided by large-scale chemical enterprises. The protection and control of synchronous motors are related to the long-term and safe operation of enterprise electrical equipment. The purpose of this paper is to realize the remote vibration monitoring and fault diagnosis of multiple rotating machines and real-time online monitoring and data storage function of the vibration state of the monitored equipment. The operation is simple and stable, and therefore, the problem of the equipment can be found at the first time, which provides forward operation of the equipment for a long time. In this paper, vibration caused by unbalanced mechanical equipment is not normally monitored remotely. Taking rigid rotor rotating machine as the research object, we adopt "Web server-database server-client" structure, the structure is the core software and hardware system design, and the application of Internet of Things technology enables users to remotely monitor and analyze the vibration state of multiple rotating mechanical devices at the same time. Hardware design mainly includes processor, function chip, sensor selection, filter circuit, adaptive sampling frequency signal acquisition circuit, and temperature measurement circuit design. Software design mainly includes main program design, signal acquisition subroutine, calibration subroutine, unbalanced calculation subroutine, and GPRS network communication subroutine. Finally, the function and stability of the whole system are verified through multiple experimental analyses. The objective has finally been achieved. The remote vibration monitoring and fault diagnosis system of the rotating machines designed on this paper is of low cost and high efficiency, simple operation, and high stability, and it is essential to identify and eliminate equipment errors in time.

1. Introduction

Short rotation is a common error of the large rotary generators. Every year, some units in our country have short rotation failure. Rotor winding turn-to-turn short circuit is not a vicious fault, but the vibration problem caused by it has been plagued by power generation companies. The short-circuit fault between turns of rotor windings of synchronous generator will cause the increase of excitation current, and even harmonic current will appear in stator windings. The radial vibration of rotor will increase with the aggravation of short circuit [1]. Rotating machines and equipment inevitably lead to an imbalance in the turn because of the uneven density

of materials, structural asymmetry, and installation errors during operation. Vibrations and strong vibrations not only accelerate the damage to the parts, they prolong the replacement cycle, but they also cause significant damage and losses to property [2]. Rotating machinery vibration monitoring and fault diagnosis systems are systems that monitor and diagnose vibration conditions caused by factors such as imbalance. Its existence is of great significance to ensure the safe and stable operation of the monitored mechanical equipment. Traditional rotary mechanical vibration monitoring and fault diagnosis systems typically operate offline. At this time, the problem of the mechanical equipment is very serious, and even if the fault can be eliminated, the life of the

affected component is greatly reduced since it has missed the best repair time [3]. Second, the data obtained by the offline system are difficult to fully utilize, and a large amount of valuable information cannot function. Moreover, conventional rotary mechanical vibration monitoring and fault diagnosis systems are complex and require specialized training. It is difficult for new workers to fully grasp the operating procedures of the entire system in a short time [4]. On the one hand, it cannot play the actual role of the system, on the other hand, it will lead to the detection system not working properly, and it is impossible to find the failure of other monitoring equipment in time [5].

With the development of the Internet of Things technology, people gradually believe that the traditional offline mechanical vibration monitoring and fault diagnosis system cannot meet the development needs of today's smart industry due to inconvenient operation and data waste [6–8]. The development of high-performance vibration monitoring and error diagnosis systems is imminent. In response to this demand, this document has designed a product based on the Internet of Things technology. "Web server-database server-client," the integrated system with core structure, can simultaneously realize remote vibration monitoring and fault diagnosis of multiple rotating machines. It has real-time online monitoring and data storage functions of the vibration state of the monitored equipment, and the operation is simple and stable. Therefore, the problem of the device can be found in the first time, which provides a positive effect for the long-term stable operation of the device.

Bengherbia et al. developed an FPGA-based wireless sensor node for machine vibration monitoring systems and fault diagnosis. The wireless node is based on the Xilinx Artix-7 XC7A35T FPGA circuit and is connected to the RF transceiver NRF24L01+ via the Serial Peripheral Interface (SPI) to form a low-cost, low-power wireless module. An additional AES (Advanced Encryption Standard) block is implemented as a custom IP core, making the transmitted data highly secure. A solution for triggering network synchronization data acquisition using the receiving node as the master node is proposed. In order to verify the effectiveness of the node, tests were carried out on a rotating mechanical imbalance test bench. The measurement results show that the designed nodes meet the requirements of synchronous data acquisition with a minimum error of 60 ns [9]. Cheng-Wei et al. and other scholars combined the PPSE method with the SVM theory to establish a fault diagnosis model for PPSE-SVM. On the basis of the rotor vibration fault simulation experiment, the process data of four typical vibration faults (rotor imbalance, shaft misalignment, rotor stator friction, and bearing housing looseness) under multipoint (multichannel) and multispeed are collected. The PPSE method is used to extract the PPSE value of these data as the fault feature vector, and the support vector machine model for rotor vibration fault diagnosis is established. From the results of rotor vibration fault diagnosis, the method has shown high precision, good learning ability, and good generalization ability. It possesses not only sensitive in the

fault type, the fault severity, and the fault location but also antinoise of the random vibration of the rotor. Therefore, it has a strong tolerance (robustness) [10].

In order to ensure the diagnosis of short circuits in real time, a long-term period is required for continuous monitoring the state of vibration and avoiding the rapid crisis of short-term damage. The offline method obviously cannot meet the requirements and can only rely on the online detection method. The structure is the core software and hardware system design. The application of the Internet of Things technology enables users to remotely monitor and analyze multiple rotating mechanical devices at the same time. The hardware design mainly includes processor, function chip, sensor selection, filter circuit, adaptive sampling frequency signal acquisition circuit, and temperature measurement circuit design. The software design mainly includes main program design, signal acquisition subroutine, calibration subroutine, unbalanced calculation subroutine, and GPRS network communication subroutine. Finally, the function and stability of the whole system were verified by multiple experimental analyses, and finally, the expected goal was achieved. The remote vibration monitoring and fault diagnosis system of rotating machinery designed in this paper has low cost, strong performance, simple operation, and high stability, which is of great significance for the timely detection and elimination of equipment failure.

2. Proposed Method

2.1. The Concept of the Internet of Things

2.1.1. Architecture of the Internet of Things. Among the many IoT architectures proposed by many experts, the EPC global "Internet of Things" architecture represented by Europe and the United States and the Ubiquitous ID (UID) IoT architecture represented by Japan are worth mentioning. Among them, the EPC global system was originally established as an international standardization body to promote the standardization of RFID technology. The following is a brief description of the EPC global and Ubiquitous ID (UID) architecture.

(1) *EPC Internet of Things System.* The EPC Internet of Things system consists of an EPC code, an EPC tag, a reader/writer, an EPC middleware, an ONS (Object Naming Service) server, and an EPCIS server (see Table 1 for details).

(2) *UID Internet of Things System.* UID is a user ID. It consists of four parts: the widely used identifier (UCode), the widely used communicator, the information system server, and the analysis server of UCode. Among them, UCode is used to identify external things, and UC is similar to PDA terminal which can read the information contained in UCode. In this way, all entities with UCode tags are connected to the information in the virtual world and establish a connection between them to achieve "everything connection."

TABLE 1: EPC Internet of Things system composition.

System composition	Name	Explanation
EPC coding system	EPC code	Specific code to identify the target
Radio frequency identification system	EPC label, reader and writer, EPC middleware	Adhering to or embedded in an object to read EPC tags
Information network system	Object Naming Service (ONS), EPC Information Service	Software support system of EPC system

2.1.2. Stratification of the Internet of Things. Regardless of the architecture, the Internet of Things is generally divided into three layers, from bottom to top: the perception layer, the network layer, and the application layer, as shown in Figure 1.

The sensing layer consists of various sensors and sensor gateways. Bar codes (1D and 2D), RFID, sensors, etc., are commonly used at this level, which can collect information about a target object anytime and anywhere. The main technologies involved in the sensing layer are radio frequency (RFID) technology, sensing control technology, and wireless communication technology. Each technology is currently in a state of continuous development and gradual renewal, such as the development of chips, the research of label materials, and the improvement of communication protocols.

Stator winding short circuit, rotor winding fault, and eccentric vibration are the three common faults of wind turbines. Researchers and students at home and abroad have paid attention to the investigation of the eccentricity of the rotor and have done more in-depth research at the same time. Rosenberg was the first to study the monitoring and control of rotor eccentricity. Since then, many results have been obtained in the analysis of the electromagnetic field and the asymmetric distribution of electromagnetic force caused by rotor eccentricity. Foreign scholar Cameron et al. used the traditional magnetomotive force and magnetic guided wave method under static eccentricity of the motor to calculate that when the air gap eccentricity of the motor occurs, current components of different frequencies will be generated in the stator winding, and they have carried out experimental verification.

The application layer is the connection between users in the Internet of Things and in the application domain. Modern agriculture, smart cities, security monitoring, new medical care, environmental monitoring, and many other fields can gradually realize the Internet of Things, and different fields are constantly trying. The Internet of Things combines the characteristics of different fields and industries and establishes an application layer that combines industry requirements to realize the intelligent application of the Internet of Things. The application layer transmits the data perceived by the sensing layer through the network layer and provides specific services for users through information integration screening, analysis, and processing. Today, the very popular “big data” and “cloud computing” are storing large amounts of data on the platform for storage analysis. They are an important part of the IoT network layer and the basis for realizing customer needs at the application layer. The ultimate goal of the Internet of Things is to “talk” to each

FIGURE 1: Stratification of the Internet of Things.

other in the application layer. According to the types of IoT applications, it can be divided into monitoring type (environmental monitoring and logistics tracking), query type (intelligent retrieval and remote viewing), control type (smart home and intelligent control), and scanning type (ETC and scan code payment).

It can be seen that the first layer of the Internet of Things is the basis for the application of the entire Internet of Things system; the network layer is the reliable guarantee for the information transmission of the Internet of Things system; the application layer is the final performance of the entire Internet of Things system, the core of networking. Only the detection layer and the network layer can be used as a basis to ensure that the Internet of Things is fully used and applied to Internet of Things. After that, the development of the Internet of Things will pay more attention to the application layer and gradually cover all industry sectors.

2.2. Key Technologies of the Internet of Things

2.2.1. ZigBee Wireless Network Technology. The three operating bands of ZigBee technology are 2.4 GHz, 915 MHz, and 868 MHz. It is the most commonly used frequency band in the ISM world and has a data transfer rate of up to 250 kbps. The 868/915 MHz band is mainly used for industrial control, sensing, and remote control. Their transmission rates are 20 kbps and 40 kbps, respectively. ZigBee technology is mainly used to carry work with small data traffic. It can be embedded in a variety of devices, and it also

supports geolocation. ZigBee technology has made great achievements in the fields of system control, office automation, industrial control, and so on. As an emerging technology in the field of wireless communications, ZigBee has been widely used due to its unique characteristics. Compared to other wireless communication technologies, ZigBee technology has the following five main features:

- (1) Safe and reliable: the ZigBee network integrates the IEEE802.15.4 protocol security mechanism and has a 128-bit security level for Advanced Encryption Standards. IEEE 802.15.4 itself has three levels of security, i.e., no security mode, the device using AES symmetric ciphers in access control lists, and data transmission.
- (2) The system has low power consumption and short delay. Low power consumption is the focus of the ZigBee protocol design. Sensor nodes are generally distributed in farmland and other field places, and frequent battery replacement is very difficult. Due to the low power consumption design of the ZigBee protocol, each node of the terminal is in a sleep state for most of the time, which greatly reduces the power consumption of the system. The device can be powered by battery for months or even years. Low rate is an important point of ZigBee transmission characteristics. This means that the amount of information transmitted is relatively small, and the time to send and receive information is very short.
- (3) Highly scalable: the radio coverage of a single ZigBee device is in the range of 1 to 100 meters, but in the tree and mesh networks, the relay function of the router can theoretically achieve up to 65,535 network nodes, which greatly expands the coverage of the wireless network.
- (4) Low cost: at present, the radio frequency hardware conforming to the ZigBee standard has been mass-produced, and the price of a single chip has dropped to an average of about 40 yuan. In addition, due to its small size, simple installation, and manual battery replacement in the case of standard battery power, this range of features reduces associated costs.

2.2.2. WCDMA Mobile Communication Technology.

WCDMA is the English abbreviation of wideband code division multiple access. It is a 3G technical specification extended on the basis of GSM network. Specifically, WCDMA is derived from wideband code division multiple access (CDMA), which provides higher data rates for mobile devices than existing communication technologies on the market. WCDMA uses direct sequence spread spectrum code division multiple access (DS-SS) and frequency division duplex (FDD), with a chip rate of 3.84 Mcps and a carrier bandwidth of 5 MHz. It supports voice, video, and data and video communications between mobile/handheld devices at rates up to 2 MB/s (for LANs) or 384 kB/s (for broadband networks). Narrowband CDMA uses a carrier frequency of 200 kHz width, while W-CDMA uses a carrier

frequency of 5 MHz width, so it has better network capacity, communication quality, and network coverage. As a wireless communication technology, WCDMA has its own unique advantages in addition to the advantages of low cost, short construction period, good adaptability, good scalability, and easier maintenance of equipment.

The frequency is wider. Compared with the narrowband CDMA2000 frequency point bandwidth, WCDMA selects a frequency bandwidth of 5 MHz, which is four times that of CDMA2000. It is capable of selecting a bit rate of up to 3.84 Mcps, which is more than three times that of a narrowband CDMA2000 code rate of 1.2288 Mcps. In this way, WCDMA can supply several times the uplink and downlink traffic rates of narrowband CDMA, which is especially helpful for improving the user experience of data services.

More services: as a third-generation mobile communication technology, WCDMA is compared to the two previous generations of mobile communication technologies. Its main feature is its ability to provide colorful mobile multimedia services. In addition to frequently used services such as voice service (CS12.2), video call service (CS64), packet data service (PS64/PS128), and high-speed packet data service (HSPA), WCDMA can also support users to use multiple services simultaneously. For example, a combination of voice services and data services, multiple concurrent services, and the like.

More reuse: WCDMA selects various multiplexing technologies. For example, voice and data are mixed together to implement channel coding and transmitted on one physical channel. For example, power multiplexing technology is selected to mix R99 service and HSPA service on the same carrier frequency. The transfer can be achieved.

2.3. Artificial Neural Network Fault Diagnosis Method

2.3.1. BP Algorithm. The BP network is a multilayer perceptron trained by the error backpropagation algorithm, which is one of the most important ANN models. The BP network is a one-way propagation multilayer forward network. In addition to the input and output nodes, the network has one or more hidden layer nodes and is not coupled in the same layer node. The input signal passes through the input layer node, passes through the hidden layer node, and then passes to the output node. The activation function of a node must be divisible, not decremented, and is usually considered a sigmoid function. If there are more hidden layers in the BP network, a smaller number of weight adjustments can make the network aware of the knowledge of the samples and store them in the form of weight distributions. However, if there are too many hidden layers, the amount of weights that need to be adjusted will also increase greatly, so e-learning requires more time. In theory, if the number of hidden layer neurons (nodes) can be arbitrarily set, a three-layer BP neural network with a hidden layer can

approximate any continuous function with arbitrary precision. Therefore, in most applications, a three-layer BP neural network with only one hidden layer is used.

The BP network learning training process includes two processes of forward propagation of the input vector and backpropagation of the error. For the training samples, the feature vector is input into the ANN, and the forward propagation of the ANN is calculated to obtain an output. The output is then compared to the expected sample output, and if there is a deviation, the deviation is propagated back from the output layer. The network weights and thresholds of the connections are adjusted so that the expected output of the network is as consistent as possible with the output of the sample.

For a BP network with three levels, assume that the number of nodes in the input layer is n , the number of nodes in the output layer is m , the number of nodes in the hidden layer is I , the total number of samples is N , and the input vector is $(x_1, x_2, \dots, x_n)$, and if w_{ji} indicates the weight between the hidden layer node and the input layer node, then the input and output of the hidden layer node are as follows:

$$\text{NET}_j = \sum_{i=1}^n (x_i * w_{ji}), \quad (1)$$

$$O_j = f(\text{NET}_j). \quad (2)$$

Usually, the sigmoid function is chosen as the function f of the node:

$$f(x) = \frac{1}{1 + e^{-x}}. \quad (3)$$

Assuming that the weight of the output layer node is k and the hidden layer node is w_{kj} , the output of the node k of the output layer is shown as follows:

$$y_k = f\left(\sum_{j=1}^I (w_{kj} * O_j)\right). \quad (4)$$

The error function uses a squared error function. For all samples, if batch processing is used, the total error is

$$E = \frac{1}{2} \sum_{p=1}^N \sum_{k=1}^m (y_{kp} - \hat{y}). \quad (5)$$

2.3.2. BP Learning Algorithm Improvement and Learning Parameter Selection

(1) *Improved BP Algorithm.* The traditional BP algorithm has two important problems: the convergence speed is slow, and the objective function has local minimum points. In this paper, an improved BP algorithm with three-layer feed-forward network is used as the learning algorithm of neural network. In the improved BP algorithm, the “momentum factor (α)” is added, which not only can finely adjust the correction amount of the weight but also can avoid learning

to avoid local minimization. At the same time, the batch process is used to train the network.

Specific steps are as follows:

Step 1: set all network weights and neuron thresholds to a small random initial value.

Step 2: input the P th sample input vector $[x_{1p}, x_{2p}, \dots, x_{np}]$ into the ANN, calculate the actual output vector $[y_{1p}, y_{2p}, \dots, y_{mp}]$ of the sample, and repeat the calculation from $p = 1$ to $p = N$.

Step 3: calculate the error E according to formula (5). If $E < \varepsilon$ (given the error limit), jump to step (6), otherwise perform weight correction.

Step 4: change the connection weight as follows:

$$\begin{aligned} w_{ji}(t+1) &= w_{ji}(t) + \eta \sum_{p=1}^N \delta_{jp} x_{ip} + \alpha \Delta w_{ji}(t-1), \\ w_{kj}(t+1) &= w_{kj}(t) + \eta \sum_{p=1}^N \delta_{kp} x_{jp} + \alpha \Delta w_{kj}(t-1), \\ \delta_{kp} &= y_{kp} * (1 - y_{kp}) * (\hat{y}_{kp} - y_{kp}), \\ \delta_{jp} &= O_{jp} * (1 - O_{jp}) * \sum_{k=1}^m \delta_{kp} w_{kj}, \end{aligned} \quad (6)$$

where t is the number of learning iteration steps and is used to calculate the weight change amount of $\Delta w_{ji}(t-1)$ and $\Delta w_{kj}(t-1)$ that adjusted last time, respectively. δ_{kp} and δ_{jp} are the error terms of the output layer node k and the hidden layer node when the sample p is input, respectively. η is the learning factor, which determines the amount of weight correction each time. In order to make the training easier to converge, the momentum terms $\alpha \Delta w_{ji}(t-1)$ and $\alpha \Delta w_{kj}(t-1)$ are introduced in the weight correction formula, where α is called the momentum factor.

Step 5: turn (2).

Step 6: the training is over.

2.3.3. *Selection of BP Network Learning Parameters.* When using BP neural network for fault diagnosis, reasonably select the connection weight matrix w , the nonlinear differentiable decrement function f , the learning rate η , the momentum factor α , the number of hidden layer nodes, and the learning samples, etc., which are accurate and fast. Effective diagnosis is very important.

(1) *Selection of Initial Value of Weight.* If the initial value is too large or too small, it will affect the learning speed. Generally, the initial value should be selected as a uniformly distributed fractional experience value, and the initial value is set to a random number.

(2) *Selection of Learning Rate η .* The choice of learning step size η is more important. The value of η is large, and the change of weight is larger, the convergence speed of BP

network learning is fast, but the η value is too large to cause oscillation, that is, the network is unstable; the value of η is small, which can avoid the instability of the network, but the convergence speed is slow. Moreover, adding a momentum factor effectively solves this contradiction. The η value in this paper was determined by repeated experiments.

(3) *Determination of Momentum Factor.* When the momentum factor satisfies $0 \leq \alpha \leq 1$, the sequence converges, and when $\alpha = 0$, it does not contain the momentum term. The theoretical α can be either a positive number or a negative number. But in practical applications, we take $0 < \alpha < 1$. The alpha value in this paper was determined by trial and error.

(4) *Determination of the Number of Hidden Layer Nodes.* The choice of the number of hidden layer nodes is a very complicated issue. Too few hidden layer nodes may cause network training to fail or the network to be “strong”. However, too many hidden layer nodes can make learning time too long, and errors are better than some errors. Therefore, there are an optimal number of hidden layer nodes.

3. The Structural Design of the System

3.1. *The Overall Structure of the System.* Remote fault diagnosis of equipment is a combination of equipment diagnostic technology and computer network technology. The status parameters shall be collected and transmitted to the remote error detection center, which has been diagnosed by the expert or the remote diagnostic system of the diagnostic center, and the corresponding solutions shall be provided in a timely manner. Prompt maintenance of field devices ensures proper equipment operation and minimizes downtime. The remote monitoring and diagnostic system consists of two parts, one is the field data collection and transmission part, and the other part is the Web and database part. The field data collection and transmission part is the bottom layer of the system. Finally, the collected signals are sent to the database server for storage. The Web and Database Component Architecture uses a popular three-tier browser/server (B/S) model based on standard protocols to create a three-tier system: Web server, database server, and remote client. This structure provides greater flexibility and openness to the system, and the three layers are connected through a certain interface. You only need to know that interface parameters communicate with other parts, and their management and maintenance are independent of each other. The system structure and composition are shown in Figure 2.

The PC of the onsite monitoring station is directly connected to the monitoring system installed on the field device, and the device status information is obtained through the sensor. After preprocessing, it is transmitted over the network to the database server using a data transfer program. Then the user logs in to the Diagnostic Center Server (Web server) through the browser and applies the corresponding diagnostic program according to the saved database name for processing. The diagnostic results are fed back to the user by the diagnostic center. The data transfer

program is developed by C++ program, and the browser interactive interface is implemented by JSP technology. The system can continuously obtain data of the running equipment and perform equipment running status monitoring, fault diagnosis, equipment management, and control in the remote diagnostic center. The device that runs the information and diagnostic results is sent as a dynamic web page to the browser of the remote client. Fault diagnosis is the core of the system. In the background of the system, the application server mainly runs diagnostic programs and accesses the database through JDBC. The data of the remote user are processed first, and the diagnosis conclusion, diagnosis description, and fault handling opinion are automatically given according to the knowledge base and the fault judgment rule. The development platform and development language for this system are Tomcat and Java. The main functions of the system are shown in Figure 3.

Expert services are complementary to diagnostic systems. Through the online question and answer, the user provides symptoms such as faults and fault descriptions, and the experts give the diagnosis results according to their own knowledge or experience. The specific implementation is achieved through software programming. Other resources include common faults, routine maintenance, and other knowledge.

3.2. *Database Server.* The database server contains a historical repository of device status, a maintenance repository, and an expert system knowledge base. The database system should have good, almost real-time, security, portability, functionality, and transparency to support remote access to data, saving time and money. The information in the database is a reusable, remotely accessible shared resource from the on-site monitoring system, device usage department, and the like. This information is preprocessed, categorized, and then stored in a repository or knowledge base. This information should include information such as vibration, noise, speed, temperature, pressure, level, and flow at the equipment monitoring point. When you need to monitor and analyze a piece of information, you only need to remotely access the corresponding information base in the database through the web server on the browser side. The information in these repositories or knowledge bases constitutes a vertical tree structure associated with system state information for easy searching and management. The database management system is developed using SQL Server. The front-end development uses the powerful JBuilder, which uses JDBC database interface technology to implement the connection between each application module and the database server in the Web server. The characteristics of database management are as follows:

- (1) Monitoring database and historical database: the historical database mainly stores real-time data that the static database and the monitoring library forward to the historical database. Therefore, a significant portion of the data in the historical database is real-time library data plus timestamps and some statistics are obtained.

FIGURE 2: Structure of the remote monitoring and diagnosis system.

FIGURE 3: System function module.

(2) Monitoring the communication program between the database and the application: the monitoring database uses multithreading to communicate with the application, and the application sends a request through the pipeline, requesting the monitoring database to provide data. The corresponding data can be found in the library and sent to the application via the pipeline.

(3) Database management and maintenance: database management and maintenance includes storage, update, and deletion of database information and management and maintenance of database consistency and integrity. Database management and maintenance also includes security management of the database. The disk array image of the hardware system and the periodic automatic backup alarm

FIGURE 4: Main interface diagram.

FIGURE 5: Real-time monitoring interface.

management mechanism of the database provide a double guarantee for the security management of the database.

4. Discussion

4.1. Implementation of Remote Vibration Monitoring and Fault Diagnosis System. As shown in Figure 4, the main monitoring interface is the interface after the user logs in successfully. The interface can monitor the running status of all the devices of the user at the same time and update the data on the interface in real time. When the running status of the monitoring device exceeds the allowable value of the

client, the icon flashes, the speaker emits a beep, and an alarm is triggered.

The upper left side of the main monitoring interface displays information about the selected device, including the device number, the name of the device, the operator, the operator contact number, and the device address. The left and bottom left side shows the status information of the currently selected device, including status, speed, left unbalance, left unbalance phase, right unbalance, right unbalance phase, ambient temperature, ambient humidity, internal temperature 1, internal temperature 2, internal temperature 3, and there are 16 internal temperatures 4, internal temperature 5, internal

FIGURE 6: Removal of the amount of unbalanced experimental data records.

FIGURE 7: Removal of the unbalanced phase experimental data record.

temperature 6, current IP, and device data time. On the right is the device under the username. Click the appropriate tab to switch between the home page and each individual watch window.

The monitor window is used to display the specific data and historical tendencies of the particular device. You can ask the history monitoring data in the database specifying the time period. The running effect of the real-time monitoring interface of the monitored device window is shown in Figure 5. The monitored device window is located in the main monitoring interface. Multiple windows can coexist.

4.2. Rotating Machinery Remote Vibration Monitoring and Fault Diagnosis System Testing. In order to verify the detection performance of the entire dynamic balance system, the lower machine was mounted on a grinder for experiments. The vibration sensor is mounted on both sides of the grinding wheel frame, the photoelectric sensor is mounted near the grinding blade at one end of the grinding machine, and the cursor paper is mounted on the polishing plate. The process of recording the amount of imbalance is shown in Figures 6 and 7.

The first correction eliminates the 87.7% imbalance of the left channel and eliminates 80.1% the imbalance of the right channel. For the third correction, the remaining unbalanced left channel is only 1.9% and the right channel is only 2.4%. In this state, 1.4 g of the test weight was added to the 215° position on the left correction surface. The customer calculated the unbalanced amount to 1.505 g, the position was 217.5°, and the error was calculated to be 0.105 g. 2.5°, indicating that the lower machine can correctly reflect the imbalance of the system. The cause of the error may be the accuracy of the weighing instrument and the accuracy of the unbalanced position correction.

5. Conclusions

The following conclusions are drawn:

- (1) This article divides the system into three parts: Web server, database server, and client. The structure of each component is clear and the design is reasonable, and the cost is controlled while ensuring the function. Users can monitor, analyze, and diagnose the running status of all devices under their name through the client. When the equipment fails, the user can receive the notification and process it for the first time, significantly reducing potential losses.
- (2) The most important thing in remote diagnosis is remote signal mode processing: Java Applet, ASP components, and ActiveX. This article focuses on the Java Applet method and its implementation.
- (3) The research results enrich the theory and method of equipment condition monitoring and fault diagnosis and have some innovations in key issues such as remote condition monitoring and fault diagnosis and diagnosis. It explores new ways to develop advanced systems in the future and has accumulated some research experience. However, remote condition monitoring and fault diagnosis are complex systems sciences that involve multiple disciplines and require much further work.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

All of the authors declare that there are no conflicts of interest regarding the publication of this study.

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