TEST Engineering & Management

July - August 2020
ISSN: 0193-4120 Page No. 6126 - 6135

Wireless Radio Frequency Monitoring Trend Forecast of Internet of Things for Wind Turbines Based on Energy Decoupling Algorithm

Xiaojing Wan[1], Wenlei Sun[1], Kun Chen[1], and Xiaodong Zhang[2,*]
[1]School of Mechanical Engineering, Xinjiang University, Urumqi, 830047, China
[2]School of Mechanical Engineering, Xi'an Jiaotong University, Xi'an, 710049, China

Article Info
Volume 83
Page Number: 6126 - 6135
Publication Issue:
July - August 2020

Article History
Article Received: *25 April 2020*
Revised: *29 May 2020*
Accepted: *20 June 2020*
Publication: *28 August 2020*

Abstract

With the increasingly strict environmental protection, the renewable energy represented by wind power generation has received increasing attention. However, the installation location of wind power generators is relatively remote, and the natural environment is relatively harsh. In addition, due to the influence of power electronic devices such as inverters and power grid harmonics, it is prone to breaking down. In this paper, an algorithm for predicting the operating trends of wind power rotating machinery based on the energy decoupling is put forward to achieve the extraction of the operating trend characteristics of the key components in the equipment group. The Hadoop cloud computing technology is used to meet the needs of reliable storage and effective management of massive data for wind power generation. In addition, the ZigBee technology, Internet of Things (IoT) technology, and wireless sensor network technology are used to perform the real-time remote data acquisition of wind power generation equipment. The practice shows that the proposed method is feasible, which can effectively reduce the storage and computing equipment of intelligent monitoring equipment, implement intelligent remote monitoring, and facilitate the intelligent management of wind power generation.

Keywords: *Energy Decoupling Algorithm, Internet of Things (IoT), Wireless Sensor Network, Intelligent Monitoring System;*

1. Introduction

With the increasingly strict environmental protection, the renewable energy represented by wind power generation is receiving more and more attention. The vigorous development of wind power will be conducive to adjusting the energy structure, reducing environmental pollution, ensuring energy safety, and achieving sustainable development of our country. Under normal circumstances, the installation location of wind power generators is relatively remote, and the natural environment is relatively harsh. In addition, due to the influence of power electronic devices such as inverters and power grid harmonics, it is prone to breaking down [1-2]. Hence, the real-time monitoring and tracking of the operating status of wind power generation online is of highly important practical significance. Due to the relatively long distance between the generator set equipment, the traditional wired transmission requires a lot of manpower and material resources. At the same time, it has the disadvantage of weak scalability, which is not conducive to the subsequent capacity construction of wind power generation. Hence, the intelligence remote monitoring system for wind power generation based on wireless transmission has become a research hot spot [3-4]. At present, the existing monitoring system for the wind turbine unit mainly collects the temperature,

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humidity, wind direction, wind speed, and operating status of the wind turbine. Operators can understand the local operating status of each device based on these parameters. However, it is impossible to monitor the operating status of the device intuitively and comprehensively, which has restricted the operation and maintenance personnel to make real-time and fast judgments on the fault. As a result, they cannot remotely operate the equipment in time, thus limiting the rapid resolution of the failure of the wind turbine unit [5-7]. With the development of society, the video monitoring system has become increasingly perfect day by day. However, the traditional video acquisition system generally applies the wired form based on the PC platform. This solution has a huge volume and high cost, and it is difficult to implement in a long-distance and multi-point system. Furthermore, most analog video surveillance systems based on coaxial cables are subject to the limitations of factors such as wiring, power supply, installation site, installation cost and maintenance, which makes it difficult to promote and apply. In addition, it is not suitable for implementing the video surveillance of wind turbine cabins [8-9].

Although all of the above methods have implemented wireless monitoring of wind power generation effectively, all of them apply the traditional Wifi, 3G communication, WLAN, and other wireless transmission methods. Among them, the transmission distance of Wifi is generally only 50 ~ 100 m, which cannot meet the requirements for remote operations. 3G has relatively narrow bandwidth and weak real-time signal transmission capacity, which cannot meet the requirement for the acquisition and transmission of massive monitoring data of wind power equipment. The telecommunications service charges generated during the data transmission process also result in relatively high usage costs. Although the WLAN technology can meet the requirements of communication bandwidth, the transmission distance and reliability of wireless signals cannot meet the needs of remote monitoring either [10].

In this paper, the prediction of the wireless radio frequency monitoring trends of the Internet of Things (IoT) for wind turbine unit based on the energy decoupling algorithm is put forward. The wireless sensing technology is used to implement the storage and data processing of wind turbine data and carry out the effective remote intelligent monitoring of the wind power generation equipment. The Internet of Things (IoT) technology is used for wireless information acquisition, and the Wimax wireless networking technology is used for wireless transmission, which has implemented the wireless acquisition and transmission of online information of wind power generation equipment. The system only requires wireless sensor node hardware, which has simplified the physical structure of the monitoring system, reduced the system cost, and enhanced the scalability.

1.1 Cloud Computing Technology

Wind turbine unit has a large scale, complex multi-source data, and other features, which leads to the massive online status monitoring data, bringing great challenges to the storage, analysis, and processing of the massive data. Facing the massive data collected in real time by wind power generation, traditional storage equipment and data information management software can no longer meet the requirements. Cloud computing is an extension and development of distributed computing and grid computing, which can implement the integration and management of information and resources. Its platform management technology allows cloud servers to cooperate with each other and provide intensive resource configuration and information for the intelligent monitoring system.

The cloud computing technology can be used to interconnect a large number of computing nodes and network equipment to establish a large scale data center, and then provide various levels of services based on data to the users, such as the Infrastructure as a service (Iaas), the Platform as a service (Paas),

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and the Software as a service (Saas). The cloud computing architecture is shown in Figure 1 as the following.

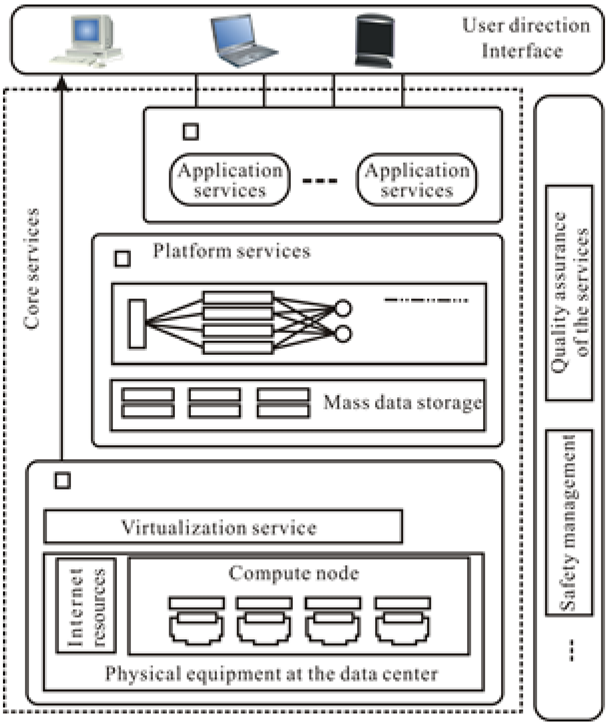

Figure 1. Cloud computing architecture

1.2 Internet of Things (IoT) Technology

The Internet of Things (IoT) technology refers to the network technology that applies sensors, radio frequency identification (RFID), global positioning system, and other information sensor devices to connect any item to the Internet, and finally implements intelligent identification, positioning, tracking, monitoring, and management of objects. It has been extensively used in the fields of industry and agriculture, logistics, etc., with great progress.

The Internet of Things (IoT) technology integrates sensors, signal receiving and generating devices with equipment, which can increase the sensing range of the sensors while saving the investment costs. Hence, it has very great advantages in remote information management and status monitoring. The details are shown as the following.

① It can collect real-time environmental information and operation data of the wind farm site intensively and provide the data to the control system of the power generation enterprise safely and effectively for decision making. ② Field-level engineering and technical personnel can use this system to control wind power equipment in real time. ③ In the central command and control system, a sensor resource cloud is constructed based on various types of information, which can improve the efficiency and level of control and command of the wind power generation equipment, and raise the level of intelligence of the remote monitoring system. ④ It has unlimited scalability and can be flexibly wired.

The Internet of Things (IoT) technology can expand the coverage area infinitely. In addition, its equipment is relatively small in size, flexible and convenient. Hence, the construction time of the project can be reduced.

The Internet of Things (IoT) has three major characteristics: 1) Comprehensive perception, where the sensors, FRID (Radio Frequency Identification), and QR codes are used to obtain various information of objects at anytime, anywhere; 2) Reliable transmission. Through the integration of the telecommunications network and the Internet, the information of the object can be accurately transmitted in real time; 3) Intelligent processing, where various intelligent computing technologies such as fuzzy recognition and cloud computing are used to analyze and process massive data, and implement intelligent control of objects. The typical architecture of the Internet of Things (IoT) is shown in Figure 2 as the following.

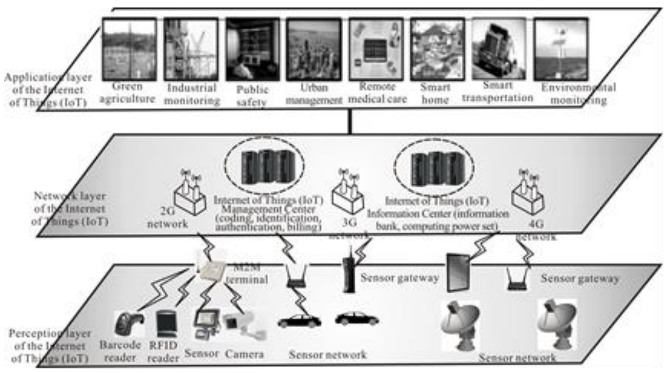

Figure 2. Typical architecture diagram of the Internet

of Things (IoT)

The Internet of Things (IoT) technology can be used to establish an “intelligent and healthy Internet of Things (IoT) for equipment operation status”, that is, to build an Internet of Things (IoT) platform for the remote safety monitoring of wind turbine unit, and provide a public service platform solution and technology service mode for real-time equipment operation status monitoring online based on the Internet of Things (IoT).

1.3 Wimax Networking Technology

The Worldwide Interoperability for Miciowave Access (WiMAX), or 802.16 wireless metropolitan area network, is an emerging wireless metropolitan area network technology. WiMAX has the characteristics of long transmission distance, high access speed, strong anti-interference capacity, high accuracy, excellent safety, high service quality, low construction cost, scalability, easy maintenance, and so on. It has been widely applied in financial network business, remote education, public safety, campus network, urban wireless service access, remote suburban communication network, and other fields.

Wimax can provide high-speed connection for the Internet, and the network coverage area is about 10 times larger than that of the mobile communication 3G base stations. Its transmission distance can reach up to 50 km. The network access speed is relatively high, and the maximum transmission speed can reach 74.81 Mbps. The bandwidth of each channel can reach 20 MHz. It has better safety and scalability compared with the wireless LAN.

From the introduction of several short-range wireless communication technologies in Table 1, it can be seen that when the Zigbee technology is used to transmit video, due to its relatively low transmission rate, it has a relatively high requirement for the image processing technology and strict requirement for the algorithm. As a result, the workload is relatively large. However, considering from the power consumption, safety, distance and other aspects, the application of the nrf2401 module as the network layer of the Internet of Things (IoT) to implement this system is superior to several other wireless technologies.

Table 1 Introduction of several wireless communication technologies

	Transmission speed	Communication distance	Frequency band	Power consumption	Safety	Main application areas
Wi-Fi	11Mbit/s~ 54Mbit/s	20m~200m	2.4GHz	High	Low	Wireless access to the Internet
Bluetooth	1Mbit/s	20m~200m	2.4GHz	Relatively low	High	Automotive, IT multimedia, industry
Zigbee	100kbit/s	2m~20m	2.4GHz	Low	Medium	Wireless sensor
Nrf2401	250kbit/s~ 1Mbit/s	200m~400m	2.4GHz~2.5GHz	Very low power consumption	Relatively high	Wireless mouse, remote control lock, etc.

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2. Internet of Things (IoT) RF Monitoring of Wind Turbine Unit Based on Energy Decoupling Algorithm

This study is performed based on the energy decoupling algorithm. The intelligent monitoring system established is mainly composed of a cloud computing subsystem and am Internet of Things (IoT) subsystem. Among them, the Internet of Things (IoT) subsystem is mainly responsible for on-site information acquisition and transmission. The wind farm IoT subsystem is a wireless radio frequency sensor network, which is composed of a large number of related wireless radio frequency nodes, which are responsible for transmitting the wind power equipment operation data acquired to the gateway through the aggregation node. The gateway node then uploads the data to the cloud computing platform through the Internet. The cloud computing platform in the cloud end is mainly responsible for the storage and processing of the wind power generation data, and the results of the data processing are provided to the remote wind power generation enterprises for query and monitoring through the Internet. Wind farm engineering technicians can use wired PC networking, mobile phones or tablet computers, and other mobile terminals to access the cloud computing platform.

2.1 Energy Decoupling Algorithm

On the basis of the IoT experimental system established according to the IoT architecture, the research on the prediction model for the deterioration trend of the operation stability of the equipment cluster is carried out. The technical scheme of the prediction mode is put forward. The method for the comprehensive perception, reliable transmission and intelligent processing of relevant information based on the Internet of Things (IoT) is studied. In addition, the method for predicting equipment failure and intelligent processing based on field measured data is explored.

(1) Research on the method for the feature extraction of variable-condition rotating machinery operation stability deterioration trend.

The fault development of wind turbines has the long-range feature. Non-fault factors such as changes in the operating conditions during the long-range operation can lead to signal energy changes. Fault development trend information is often overwhelmed by the non-fault change information. Hence, it is difficult to implement the trend prediction of equipment development status effectively by using the traditional fault feature extraction method based on the energy change. The fault trend feature extraction algorithm based on energy decoupling is studied to explore the energy decoupling and blind source separation feature extraction system with a dynamic nonlinear topology. It has eliminated redundant information caused by non-fault energy changes to a large extent, making the extracted characteristics of the fault development trend weakly coupled or separated from the non-fault change characteristics such as the changes in the working conditions of the electromechanical system. Thus, the prediction model is further established.

The nonlinear independent component analysis (CICA) method is used for blind signal separation to purify energy information and suppress interference information. It is mainly aimed at the vibration information of transmission shaft and bearing as well as the current and power information of the generator. ICA is used to separate the fault information. The ICA estimation method that maximizes the non-Gaussianity is adopted to obtain the information about the fault-free and fault-related characteristics. Secondly, the matrix generalized feature decomposition method is used to select the auto correlation matrix of the signal and calculate the generalized feature vector of the matrix bundle, to obtain the information separation matrix, improve the speed and accuracy of the information separation, and obtain the fault-related feature quantities

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quickly.

(2) Research on the prediction method for the operating stability deterioration trend of the rotating machinery under variable working conditions. The stability deterioration trend characteristic information is an early failure information. In order to implement the effective prediction of the failure development trend, an adaptive selection of the trend prediction method is established, and the relevant knowledge mining tools are developed to make decision operations. It can carry out adaptive selection based on the accuracy, stability and real-time performance of the prediction model, implement the automatic selection of the multiple trend prediction models, and adaptively improve the performance of the prediction model. The technical route for predicting the deterioration trend of the operational stability of the wind turbine group is shown in Figure 3 as the following.

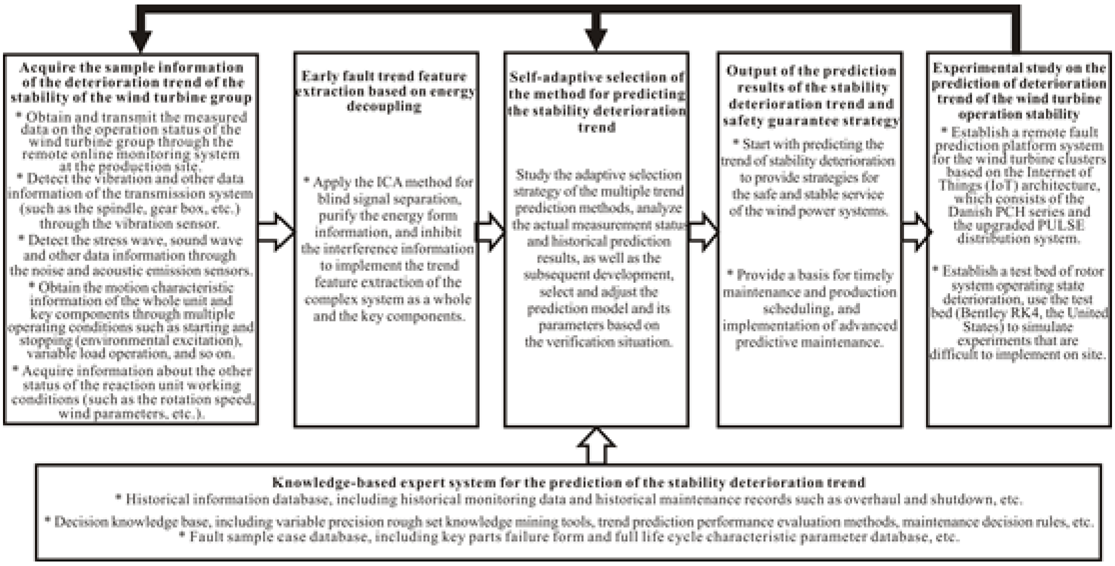

Figure 3. Technology roadmap for predicting the deterioration trend of the operation stability of wind turbine group

2.2

Composition of the Cloud Computing Platform

The Hadoop open-source cloud computing technology is used to establish a cloud computing platform for the monitoring of smart grid status. The platform mainly includes a cloud computing infrastructure layer, a cloud computing platform layer. Among them, the cloud computing infrastructure layer mainly includes a massive data management system, a distributed storage system, a cloud computing operating system, and a server cluster. Based on the server cluster, resources can be virtualized by using the virtual machine, and the distributed storage system can be used to store and manage massive data. In addition, a status data parallel processing system based on MapReduce is designed, which can provide high-performance parallel computing capabilities for state assessment, diagnosis and prediction. The architecture of the smart grid status monitoring cloud computing platform is shown in Figure 4 as the following.

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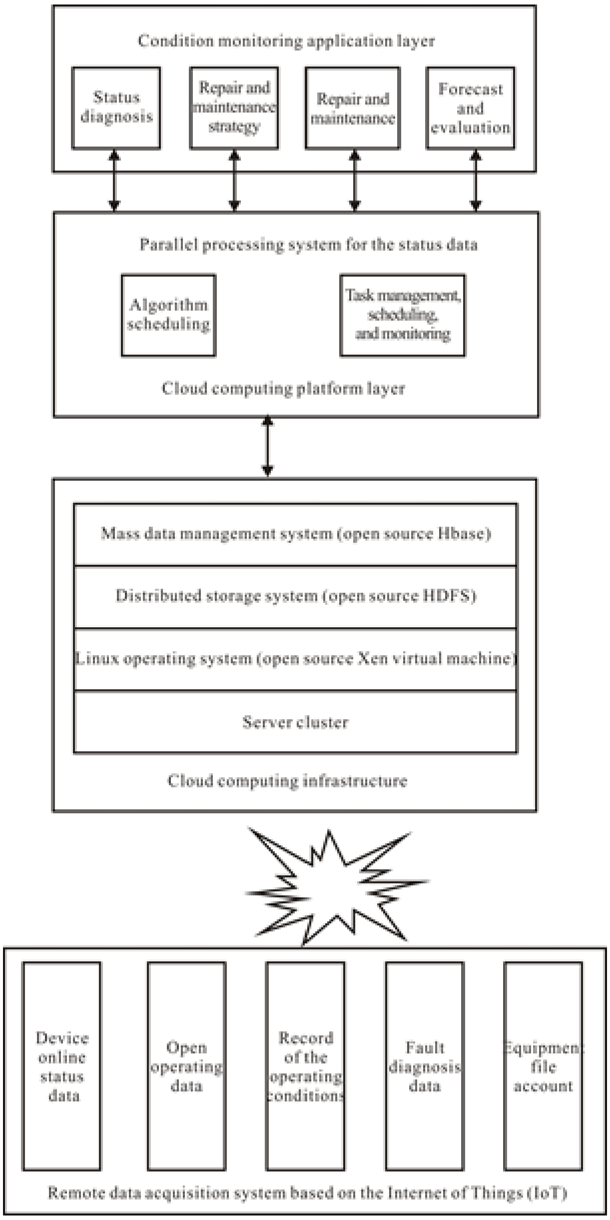

Figure 4. Software architecture

2.3 Wireless Sensor Network

In this paper, the Zigbee radio frequency chip CC2530 developed by TI is selected as the processor chip, which has integrated the processor module and the wireless transceiver module. The 51 single-chip core and one radio frequency module are integrated internally. DC4.5V is used to supply power to the entire sensor node. The wireless sensor nodes of the CC2530 RF module can self-organize and form a wireless multi-hop network based on the communication protocol. The acquired operation data of the wind power generation equipment are gathered at the aggregation node through the sensor node, and then transmitted by the aggregation node to the gateway. Finally, the gateway uploads the data to the cloud computing platform through the Internet. The hardware structure of the network node and the aggregation node are shown in Figure 5 and Figure 6, respectively.

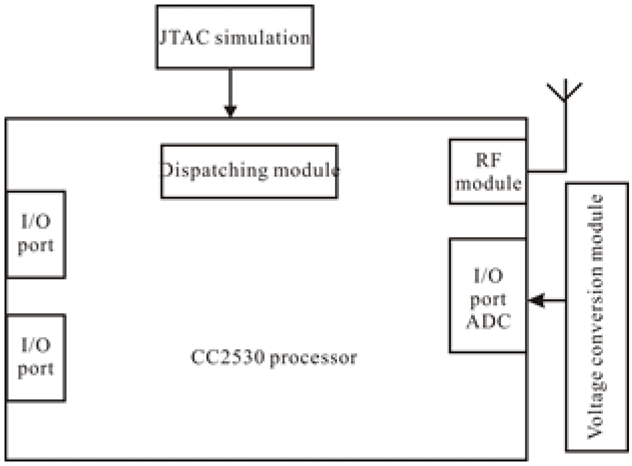

Figure 5. Diagram of the node hardware structure

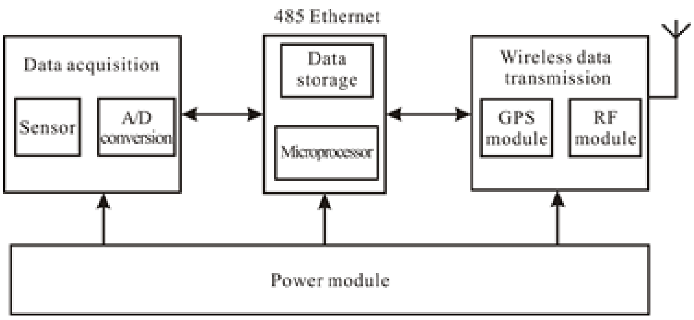

Figure 6. Diagram of the convergence node structure

The network structure of the wind power equipment terminal is shown in Figure 7 as the following.

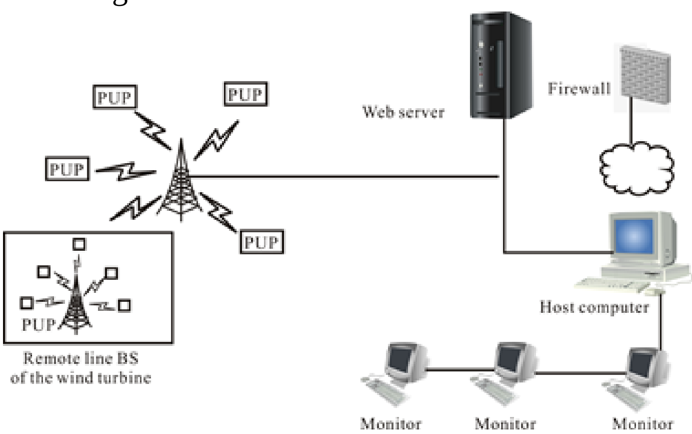

Figure 7. Wimax network structure

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The sensor collects data on the operating status of wind power generation equipment periodically. After the processing at the Wimax physical layer and the MAC layer, the data will be sent to the remote base station and finally transmitted to the central base station. During this process, the base station allocates the bandwidth dynamically according to the network coverage. Taking into consideration that electromagnetic interference should be avoided during transmission, optical fiber cables are used to connect the central base station to the Internet, and at the same time upload the data on the operation status of wind turbine equipment to the cloud computing platform, thereby implementing the cloud storage and processing of data. The authorized users such as the engineering and technical personnel can monitor the operation status of the wind power generation equipment remotely and intelligently through the Internet or mobile 3G/4G.

There is no relay base station between the remote base station and the central base station. Hence, the remote base station of the wind power generation equipment can directly communicate with the central base station. The 5.8GHz frequency band is adopted between the base stations, and the 3.5GHz frequency band is adopted for the communication between the wind power generation equipment and the remote base station. In the aspect of frequency coverage, although there is partial overlap in the remote base station and the central base station, the frequency bands used are different and will not cause interference due to the same frequency.

2.4 Framework of the Wind Power Intelligent Monitoring System

According to the above analysis, the overall framework of the wind power intelligent monitoring system is shown in Figure 8 as the following. In the figure, the wind power monitoring storage subsystem based on the cloud computing platform communicates with the wind power intelligent monitoring subsystem based on the Internet of Things (IoT) through the Internet. Remote monitoring can be directly accessed through the Internet or via the mobile 3G/4G.

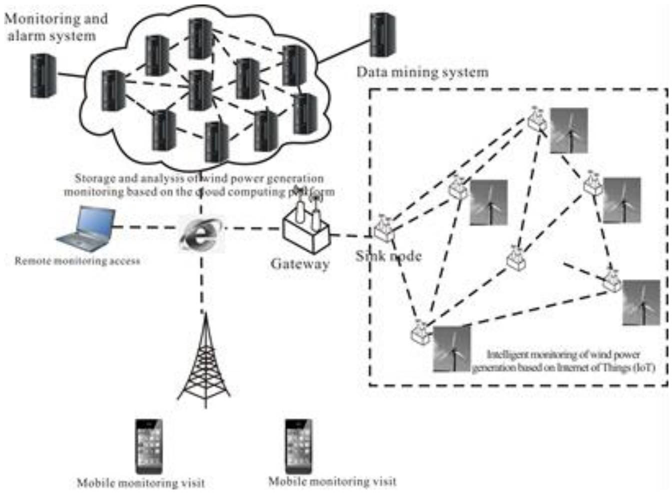

Figure 8. Overall framework of the intelligent monitoring system for wind power generation

3. Case Analysis of the Remote Intelligent Monitoring Trend of Wind Power Generation

In order to verify the effectiveness and rationality of the scheme proposed in this paper, remote intelligent monitoring of the WT2000 variable speed wind turbine in a wind farm is carried out. The main parameters of the unit are shown in Table 2 as the following. The main status characteristic parameters include the impeller speed and the blade motor temperature of the impeller system, the gearbox temperature and the bearing temperature of the transmission system, the tower vibration acceleration, the generator speed and the winding temperature of the generator system, the temperature of the cabin of the hydraulic system and the yaw frequency converter of the yaw system, etc.

Table 2。 Fan parameters

Parameter	Numerical value
Rated power / MW	2
Rated wind speed / $m \cdot s^{-1}$	12
Cut-in wind speed / $m \cdot s^{-1}$	3
Cut-out wind speed / $m \cdot s^{-1}$	22

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Wheel height / m	65
Impeller diameter / m	70

The operational data used for condition monitoring in this paper are the data collected in November 2019. Compared with the traditional methods, the main performance of the wind power monitoring system based on cloud computing and Internet of Things (IoT) technology is shown in Figure 9 as the following.

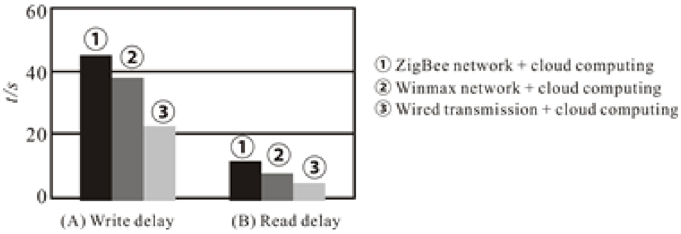

Figure 9. Performance comparison diagram

From Figure 9, it can be seen that the monitoring based on the energy decoupling algorithm has a relatively high advantage in the aspect of transmission delay and data accuracy.

4. Conclusions

In this paper, an intelligent monitoring system framework for wind power generation based on cloud computing, Internet of Things (IoT), and wireless sensor network technology is designed. This method has the following advantages: The cloud computing technology is used to greatly reduce the hardware investment of the wind power generation monitoring system significantly, which can effectively save the cost of computation and storage; ② The wireless sensor network established based on Wimax has the capacity of remote information acquisition and transmission, and has relatively powerful scalability. The application of engineering practice shows that the intelligent monitoring system for wind power generation based on cloud computing and Internet of Things (IoT) technology has better performance than the traditional monitoring methods in the aspect of transmission delay and accuracy.

Acknowledgements

This research is supported by National Natural Science Foundation of China (No.: 51565055 and No.: 51765062); Science and Technology Support Projects of Xinjiang Uygur Autonomous Region (No.: 2017E0276); Science and Technology Innovation Program for Doctoral Students (No.: XJUBSCX-2014019).

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