RESEARCH AND APPLICATION OF THERMAL ENERGY RECOVERY AND AUTOMATIC MONITORING SYSTEM FOR MOTOR EQUIPMENT

by

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In order to achieve an automatic monitoring system for the operation status of motor equipment, the author proposes a research and application based on the thermal energy recovery and automatic monitoring system of motor equipment. The author first analyzes the operating characteristics of the motor and collects four basic parameters of the motor, namely voltage, current, speed, and temperature, in order to determine whether the motor is in normal working condition. Secondly, the system combines electrical parameter detection and acquisition, wireless network technology, industrial field bus technology, and computer user software to achieve remote real-time monitoring, control, and management of the motor's remote travel status. This enables the entire system to achieve intelligent, networked, and systematic management, solving the technical problem of real-time control and system management that cannot be achieved in motor systems distributed in multiple locations. Finally, the monitoring results indicate that after installation and debugging, the data is displayed on the upper computer. This effect is the data collection of the motor during low speed operation, which is reflected in real-time on the control panel. The actual parameters of the motor were compared with the test parameters of this system, and the test basically achieved the desired effect, with accurate detection data.

Keywords: *motor equipment, automatic monitoring, parameter collection*

Introduction

In recent years, with the increasing emphasis on energy conservation and emission reduction in the country, the power industry has also continuously increased its efforts in energy conservation and consumption reduction. In order to achieve energy conservation and consumption reduction, as well as improve quality and efficiency, in recent years, State Grid Corporation of China has comprehensively promoted energy conservation and consumption reduction work from the aspects of grid technology transformation, grid operation optimization, grid safety management, and power quality optimization. Due to the inability of some motor equipment to automatically monitor and alarm in a timely manner when malfunctions occur, the author proposes a set of thermal energy recovery and automatic monitoring system for motor equipment on the basis of improving system reliability and economy. The application of this system provides strong guarantees for improving the safety, reliability, and economy of system operation. The thermal energy recovery and automatic monitoring system for motor equipment mainly consists of a data acquisition layer, a network communication layer, a data management

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layer, an application support layer, and a display terminal layer. Among them, the data collection layer is mainly composed of several collection units, such as intelligent meters, electric valves, liquid level sensors, pressure sensors, *etc*. The network communication layer is mainly composed of several network devices, such as fiber optic transceivers, microwave transceivers, *etc*. The data management layer mainly consists of several application servers, such as database servers, web servers, *etc*. The application support layer mainly consists of several software components, such as intelligent meter software, electric valve software*, etc*.

The data collection layer is responsible for collecting the operating parameters of the motor equipment, such as current, voltage, frequency, power, *etc*. The network communication layer is responsible for collecting signals from on-site sensors and transmitting them to the network communication layer, while also processing and analyzing the collected signals. The application support layer is responsible for transmitting the processed data to the display terminal layer through the network communication layer. The display terminal layer is mainly responsible for displaying the processed data in real-time in the form of graphics or reports. The data collection layer is mainly composed of multiple intelligent meters, electric valves, liquid level sensors, pressure sensors, and other devices. Among them, the function of smart meters is to collect real-time operating parameters of motor equipment, upload them to the network communication layer for processing and analysis, and transmit the processed data to the display terminal layer through Ethernet. Electric valves are an important component of the thermal energy recovery and automatic monitoring system for motor equipment. Their function is to detect the operating status of the motor equipment and issue control signals based on the detection results, achieving real-time adjustment of the temperature, pressure, meteor and other parameters of the motor equipment. The liquid level sensor is mainly used to detect the liquid level in the water tank or pool, and its function is to real-time detect the water level in the water tank or pool. The pressure sensor is mainly used to detect the pressure of the medium inside the pipe-line, and its function is to monitor the pressure of the medium inside the pipe-line in real-time. For situations with multiple pump sets or valve devices, these devices are usually installed in the same main control room and communicate with the network communication layer through Ethernet. The data collection layer achieves real-time monitoring of the operating status of motor equipment through various sensors, and at the same time, the monitoring results are transmitted in real-time to the application support layer through Ethernet. In addition, intelligent meters, electric valves, liquid level sensors, pressure sensors and other devices can also online check the operating status and fault information of side motor equipment, providing rich data resources for the data management layer [1, 2].

Literature review

In the application process of thermal energy recovery and automatic monitoring system for motor equipment, firstly, programmable logic controller (PLC) is adopted as the control core of the thermal energy recovery and automatic monitoring system for motor equipment. At the same time, it is connected to the upper monitoring software to monitor and control the operation status of the entire system in real-time through the upper monitoring software, ensuring the safety and stability of the entire system. Secondly, the thermal energy recovery and automatic monitoring system of motor equipment was applied to different types of motor equipment, achieving the thermal energy recovery and reuse of different types of motor equipment. Finally, through the analysis of data during the control process, it is possible to evaluate the effectiveness of thermal energy recovery and reuse of motor equipment, and decide whether to continue using the system based on the evaluation results. Through actual operation, it can be seen that the application of thermal energy recovery and automatic monitoring systems for motor equipment can achieve good energy-saving effects in different types of motor equipment. Taking a certain enterprise as an example: the enterprise currently uses two variable frequency variable speed AC asynchronous motors with a rated current of 374A. Due to the fact that the enterprise is located in a northern region with low winter temperatures, it is necessary to heat two electric motors with a heating power of 1031 kW to ensure normal production. In actual operation, the enterprise needs to heat two electric motors in winter. The application of the thermal energy recovery and automatic monitoring system for the motor equipment of the enterprise in different types of motor equipment can effectively recover the heat generated by two motors, thereby improving the safety and stability of the enterprise's motor equipment, reducing production and maintenance costs. Ghoshal *et al*. [3] constructed an efficient unmanned monitoring system due to their own automated monitoring and management system. This system can collect real-time data and related parameters in the power grid, judge its operation status, analyze whether there are safety hazards, and issue an alarm to the staff when the relevant data deviates significantly from the normal value, urging them to carry out maintenance work and avoid loss problems caused by fault continuation. Kaneko *et al*. [4] used computer technology to achieve unmanned monitoring, as well as prioritizing the detection of hidden dangers and faults, and automatically analyzing and processing faults. After the application of the new system, not only can real-time tracking of the operation status of equipment within the site be achieved, ensuring the correctness and accuracy of relevant leadership decisions, but also the regulation of power transmission of related motor equipment can be achieved. Reduce losses caused by related equipment failures or accidents, and improve decision-making efficiency.

Methods

Overall system design

The functions of the thermal energy recovery and automatic monitoring system for motor equipment mainly include the following aspects:

– Real time monitoring of motor equipment, automatic control based on the status of different equipment, such as temperature monitoring of the motor and speed control of the water pump.
– Based on the real-time monitoring of the motor equipment status, remote control is carried out, such as completing relevant operations through remote control in case of system failure.
– The monitoring system can also achieve automatic switching of multiple states, such as automatically switching to standby state according to on-site conditions in case of system failure, thereby ensuring the safety of the system.
– The thermal energy recovery and automatic monitoring system of motor equipment can also achieve energy-saving and consumption reduction functions based on the actual operation of the equipment, such as: when the motor equipment malfunctions, the heat recovery function of the motor equipment can be achieved through remote control to ensure the economic efficiency of the system [5].

The working process of the system is to collect data from various parameter acquisition modules installed in the motor equipment, and then send the data to the main controller through the RS-485 interface. The main controller displays and combines the various parameters into a data string through LCD12864, sent to the GPRS wireless module through RS-232, the GPRS wireless module combines the data string and its own address data and sends them to the internet. Then, the PC receives the data sent by each GPRS wireless module through the internet and processes and displays it. If a motor malfunctions, the PC can send commands to various communication nodes and then send shutdown commands to the parameter acquisition module or execution module based on the commands. The overall system design diagram is shown in fig. 1.

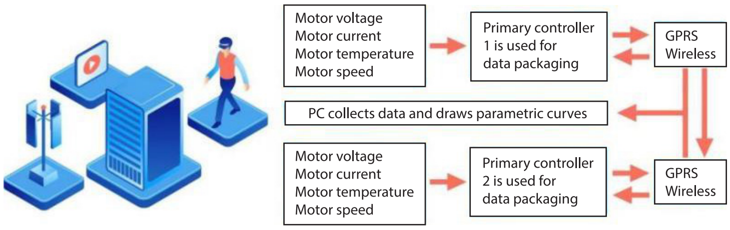

Figure 1. Overall system design

Online monitoring of motor transformer. In a certain period of time, the real-time detection operation of the transformer data can be called the online monitoring of its development, through which the change of the actual operating state of the equipment can be recorded, and the staff can be warned when there is a failure. This real-time monitoring can be carried out when the equipment is running, without interference from whether the equipment is running, which is also its biggest feature. When there is a fault inside the transformer, the data obtained from the implementation of monitoring has a certain degree of limitations for the analysis of this fault, but this cannot prevent it from becoming the main way of fault detection of power equipment at present. In real-time monitoring, the sensor has played a greater role, with a good performance of the sensor, then the monitoring effect will be better, the level of intelligence will have a certain degree of improvement, reducing the maintenance cost of automated detection system.

Partial discharge monitoring. In the daily operation of the power equipment, the longer the time, the wear and tear of the power equipment, the aging of the insulation performance will gradually become serious, and more impurities will enter. The aforementioned situation will make the insulation material inside the power equipment abnormal, affecting the normal function of the power equipment. The main reason is that these impurities will cause certain abnormal phenomena in the electric field strength of the equipment. In the actual operation of the equipment, the special area with relatively more impurities will maintain a high parameterization of the actual electric field strength, and the area with relatively less impurities will also have a relatively small electric field strength. If a relatively high intensity is generated in a specific area, the field strength will be relatively small. It will lead to the phenomenon of electric field breakdown at the position, and further discharge changes, which can be called partial discharge. This kind of special discharge phenomenon is not attributed to the impact of penetration, but a small part of the insulation has been damaged, the major threat of partial discharge, mainly for the special charged particles in the discharge process, which constitute a significant impact on the relevant medium, in the case of partial discharge time is too long, the insulation medium under the influence of long-term impact. It can cause problems such as aging and even damage. In the process of aging of the medium, the corresponding active substances and other elements will be derived and formed, which will further accelerate the aging phenomenon caused by the medium, and even cause damage. In this process, the electric field intensity around the discharge position and surrounding area will increase continuously.

In the special process of the pulse signal, the supporting free electrons first produce a special separation effect through the corresponding atoms or molecules, and then rely on the special acceleration effect of the power plant, the focus is on the corresponding current amplitude increase. After a relatively short period of time, the acceleration effect decreased. When the charge running parameter is not constant, the corresponding transient electromagnetic wave will be released. Through the basic theory of the signal, it can be found that its time domain and frequency domain characteristics, there are different characteristics, the actual pulse signal duration is shorter, then the spectrum will be relatively wider. The occurrence of the local discharge signal can be described:

$$i(t)=\frac{1}{T}te\left(\frac{1-t}{T}\right) \tag{1}$$

where t is the actual duration of the local discharge pulse signal, I – the peak parameter, T – the actual signal rise time, and e – the instantaneosus electromotive force, so the specific discharge parameter is:

$$q = EIT \tag{2}$$

According to the time-domain characteristics of the previous formula, the basic amplitude-frequency characteristics can be obtained through the matching Fourier transform:

$$I(w)=\frac{q}{j+Tw} \tag{3}$$

where T_w is the time domain and j – the frequency domain parameter.

Main controller design

The function of the main controller is to receive the data collected by the motor parameter acquisition module through the RS-485 bus, verify and ensure that the data is correct, then display the collected data on site, package it according to the specified protocol combination, and send it to the GPRS wireless transmission module through RS-232. After receiving the data from the collection module, it can be displayed on-site on the LCD screen and send instructions to the motor. In order to achieve stable and accurate data transmission, the design of this system must suppress pulse interference. Optoelectronic isolation is used on the main controller to electrically separate the easily affected parts of the equipment from interference sources, maintaining only the connection between optical signals and not directly through electrical connections.

The GPRS communication design

The GPRS module has two RS232 interfaces, with UARTO as the main interface and UART2 as the GPS output interface. The module can operate in both automatic positioning mode and modem mode. When the module is in automatic positioning mode, it will automatically connect to the GPRS network after being powered on and regularly transmit GPS data information the GPRS network. The UART0 is a transparent data interface, and users can send data to the network through this serial port. When the module operates in Modem mode, UARTO serves as the GPRS module interface, which allows users to communicate with the GPRS module (MC37I). The module defaults to automatic transmission mode. This system sets the GPRS module to automatic transmission mode and sends and receives data through RS-232.

Detection module design

This system will collect four basic parameters of motor voltage, current, speed, and temperature, which can be divided into voltage detection module, current detection module, speed detection module, and temperature detection module.

Voltage detection uses a Hall voltage sensor, which utilizes the Hall effect to sense the corresponding electromotive force. This way, the voltage is collected with the accuracy of this method. Therefore, this design uses a module that uses Hall voltage sensors to collect voltage as an online voltage collection element.

When measuring current, there are Hall current detection method and coil detection method, both of which capture the magnetic field around the current. The larger the current, the stronger the magnetic field around it. The Hall current detection method was chosen, and HBA50-TSAD is used as the current signal acquisition component. The method of measuring speed using a Hall sensor is used. After the Hall sensor detects metal, it counts once, which can achieve speed measurement with relatively small errors [6].

The temperature measurement technology adopts the embedded thermometer method, which can measure accurate temperatures at multiple points for large motors and is widely used. The selected temperature transmitter is a Pt100 platinum resistor, which can effectively eliminate the interference of the magnetic field generated by the motor on temperature measurement.

Experiments

The system adopts an upper computer program written on the LabWindows/CVI platform. The interface you designed is drawn in the panel, and each control has a callback function. Additionally, there is a cross functional operation interface between the function panels. The program framework structure can be automatically generated, and we only need to add the functional program we want to implement to the callback function under the desired button. The upper computer program design process of this system is designed based on the actual needs and functions to be implemented. The first step is to debug the serial port to ensure that the computer can communicate with the GPRS module through serial port. Then display the central map, showing the equipment operation status in various places. You can also add or remove devices and save relevant information [7].

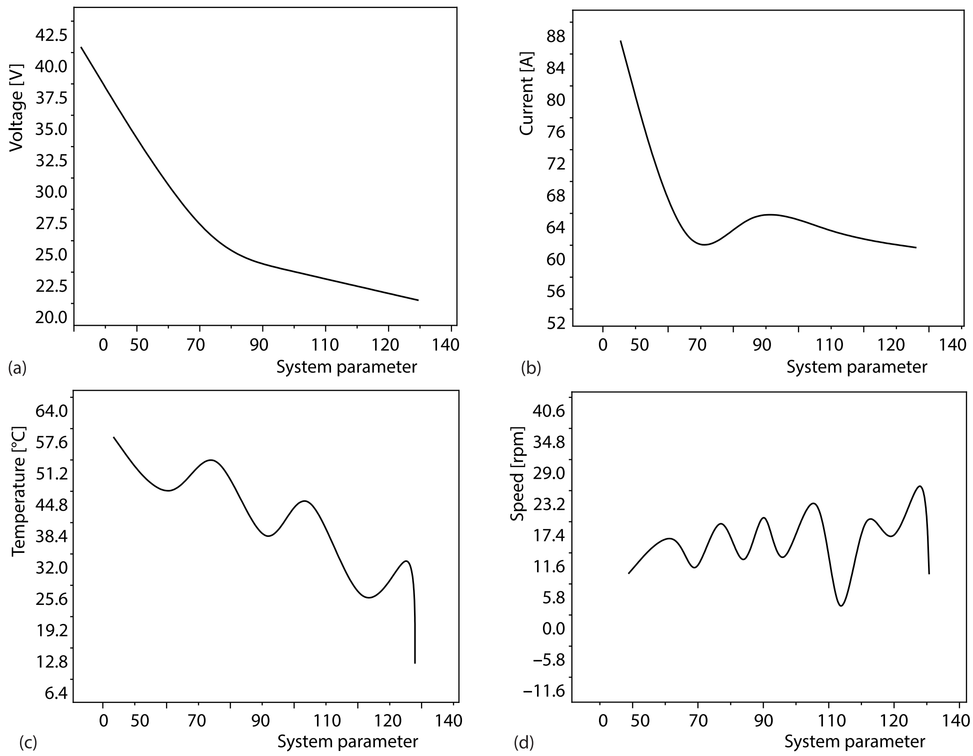

Figure 2. Measurement rendering; (a) voltage, (b) current, (c) temperature, and (d) speed

After installation and debugging, the data was displayed on the upper computer. This effect is the data collection of the motor during low speed operation, which is reflected in real time on the control panel, as shown in figs. 2(a)-2(d). Table 1 shows the comparison between the actual parameters of the motor and the test parameters of this system. The test basically achieved the desired effect and the detection data was accurate.

Table 1. Comparison of actual motor parameters with test parameters of this system

	Voltage [V]	Current [A]	Speed [rpm]	Temperature [°C]
Actual device parameters	384.8	1.63	782	18.9
Measurement value of this system	384.4	1.62	780	18.9

The remote monitoring system for motor equipment operating parameters has basically completed the functions of collecting, long-distance transmission, and on-site display of the four motor parameters, and can draw parameter curves in the Win windows window. During the collection process, the built-in AD converter of the STC12C5A60S2 microcontroller plays a significant role. It has a fast conversion rate, stable working performance, and can also reduce peripheral circuits. The use of RS485 communication bus in the design greatly improves the system's scalability and versatility, as long as the data sent by the submodules meets the protocol requirements. In the WINDOWS FORMS software, the software sets the sampling period and uses CVI GRIP to draw parameter curves for the collected parameters. The commands in the Forms software can be set independently, and the software interface is simple and powerful. The curves drawn basically meet the accuracy requirements of various parameters [8-10].

Conclusion

The advantages of this system are simple hardware design, low cost, and strong practicality. The biggest feature is the ability to achieve remote data transmission, remote monitoring, without the need for personnel to monitor on site, greatly reducing manpower investment, and the ability to operate multiple motor devices simultaneously on the upper computer, greatly improving work efficiency. This system can be used not only to collect the operating parameters of electric motors, but also to collect parameters of other electrical equipment, such as temperature and pressure of compressors, and remote monitoring. It can also be applied to remote monitoring and control of smart homes. So the remote monitoring system for motor equipment operating parameters can be used in various fields of industry, as well as in home monitoring and control. With the increasing development of the economy, there will be an increasing demand for remote monitoring systems for motor equipment operating parameters in industry. Therefore, parameter acquisition technology will also rapidly develop towards higher accuracy, faster, and more intelligent directions.

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