Design of Motor Operation Monitoring and Cooling Control System

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Abstract: Combined with PLC control technology, a motor monitoring and cooling system is designed. The main function of the system is to remotely control the motor and monitor the working environment and operating status information of the motor through the mobile phone app, and to cool the motor through the cooling system; it can effectively improve the operating efficiency and reliability of the motor, and improve the user experience. The article puts forward the design scheme of the motor monitoring system and summarizes the various functions of the system control. It also analyzes and describes the realization method and key technology of the control system in detail.

1.Introduction
The development of modern industry is inseparable from the electric motor, which is the source of power in the industrial field. However, motors in industrial production usually run uninterruptedly, and various faults are prone to occur during long-term motor operation. In order to ensure the safe and stable operation of the motor, real-time online monitoring of the motor's operating status is essential. At the same time, some motors have higher requirements for the external environment. For the purpose of ensuring the normal operation of the motors, it is very necessary to monitor their operating environment.

PLC has the characteristics of high stability and strong anti-interference ability, so this system selects PLC as the main controller to realize the monitoring and control of the motor. Considering the structural complexity of the motor, a ZigBee wireless sensor network will be established to realize wireless data transmission. The users can use mobile phone app to remotely monitor, and use the host computer to monitor the industrial site in real time. This system solves the problems of high system cost, complicated wiring, and inconvenient maintenance. It also has the advantages of remote control, friendly interface, and strong portability.
2. The overall architecture of the system

In this design, the running status and operating environment of the motor are monitored and controlled in real time. The sensors’ data which are collected from the terminal node in real time will converge to the coordinator node through the ZigBee wireless sensor network; it sends the data to the PLC controller through serial communication, carries out data calculation and processing, outputs instructions to control the frequency converter and solenoid valve, and then realizes the speed regulation and on-off of the motor to ensure its safe and stable operation. The upper computer selects the touch screen human-computer interaction interface to monitor the running status of environment and operation parameter of the motor in real time; users can remotely monitor and operate through the mobile client, which is safe and convenient. Considering that the motor will generate heat during long-term operation, a cooling system is designed; when the temperature rise of the motor exceeds the specified value, the PLC sends the processed data to the output device, controls the solenoid valve, and the cooling system starts to work; at the same time, the frequency converter is turned on to adjust the speed of motor, that is aiming to achieve the cooling effect. The overall architecture of the system is shown in Figure 1.

![Figure 1 The overall architecture diagram of the system](image)

3. Design of control system

The motor monitoring and cooling control system consists of a host computer (PC), PLC, mobile phone terminal, ZigBee wireless network, A/D conversion module, the 9 types of sensors (like temperature sensor, torque sensor or noise sensor, etc.), solenoid valves, inverters, motors, etc. The PLC hardware is composed of power supply, CPU, memory, communication interface, input/output interface, expansion interface, etc. The upper computer (PC) and PLC are connected through RS-485 serial communication interface; The PLC controller receives the sensor data through the wireless network established by ZigBee, besides, it will send the parameters to the mobile client through the Ethernet module; and the mobile client completes video monitoring through wifi module.

The upper computer (PC) selects Siemens' touch screen programming software WinCC flexible SMART V3 as the on-site monitoring system software platform of the motor. At the same time, it uses the Android development environment for related design and configuration, and the mobile client performs remote monitoring. Because the man-machine interface can realize process visualization, operator control of the process, display alarm, record, print, output process value and alarm record and other tasks, it can transmit, display, record, store, and process the collected data for meeting the various monitoring requirements. The system selects Siemens S7-200 CPU 224 PLC as the main controller. It completes program design, hardware configuration, communication port and data retention settings, and stipulate protection authority under STEP7-Micro/WIN programming environment; the controller owns 14 points of input/10 points Output, and then expands 3 EM235 analog input and output modules. The control diagram of system hardware is shown in Figure 2.
4. Software system design
The system software is composed of PLC control program, wireless network design and upper computer. Among them, the data acquisition program is the basis of the system application software, which mainly collects, analyzes, and converts the operating state of the motor. The upper computer monitoring program includes uploading data, storing, processing and analyzing, real-time monitoring, and regulating the execution mechanism.

4.1 PLC control software design
The PLC software design includes two control modes: automatic and manual. As for the manual mode, the user can control the motor to start, stop and speed regulation of the motor by the solenoid valve and inverter. In the automatic operation mode, the PLC will analyze and process the parameters of the motor operating state and the working environment. The users set the upper and lower limits of the relevant parameters by combining the standard values of motor operation and work experience; through the comparison of the set value and real-time data, the PLC outputs instructions to control actions of the actuators.

4.2 Design of wireless sensor network
This system uses the more widely used TI company CC2530 chip. Such as, the formation of ZigBee network, data transmission and reception, they are both realized through Z-Stack. And this chip fully supports the IEEE 802.15.4 protocol.

The design of wireless sensor network software includes two parts: coordinator node and terminal node. The terminal node is used to collect the data of each sensor. After the system is powered on, the system is initialized, that is, the initialization of the hardware and protocol stack, and then it searches whether there is a ZigBee network. If so, it sends a request to join the network, the terminal node will be assigned to A 16-bit network address. After completing the above series of initializations, the terminal node enters a low power consumption mode, it will wake up the node through a regular interrupt and calls a data acquisition program, afterwards, the node sends the measured data...
information to the coordinator node regularly. If the information is sent successfully, the terminal node enters the dormant state again.

The coordinator node is used to create and configure the network, supports the association, ensures the normal transmission of data information, and processes the information. First, the system initializes, searches for idle channels in the frequency band, and then establishes a ZigBee network, initializes the network parameters, at the same time, selects the 16-bit network address 0x0000 as the address of the coordinator node. Second, it waits for the node to join, when receiving the network access request from the terminal node, the coordinator node allows it to join the network and assigns it a 16-bit short address; when a node joins the network, the host computer sends a command to detect data regularly, and this command is sent to the sensor node; the coordinator confirms after receiving the data and sends the data to the PLC controller through the serial port.

4.3 Design of human-computer interaction interface
The host computer of the motor monitoring and cooling control system mainly manages the system's peripheral equipment and various key parameters, including real-time data acquisition, data analysis and processing, real-time control, definition configuration, statistical storage, screen display, and query print, communication and other functions. It can share complete monitoring information in real time and display the key parameter information of the system graphically or in text mode; query various report data and other tasks. The touch screen and mobile client can complete real-time field monitoring at long and short distances. Touch screen human-computer interaction interface is shown in Figure 5.
4.4 Design of mobile APP

The mobile client is mainly used to implement tasks, such as, user login, device management, and parameter display. First, the user logs in the account and password, and after the information is verified, directly enters the main page to display real-time parameters, automatic mode/manual mode switching, alarm status, motor start and stop, etc.

5. Design of the cooling system of the motor

Commonly used motor cooling methods include air cooling, water cooling and mixed cooling. The
motor structure, temperature, and function are different, and the cooling method selected is also different. This system is designed with water cooling method, and the cooling water channel is slotted in the casing so that the cooling water flows in from the water injection port. After circulating in the casing, it flows out from the water outlet to take away the heat generated by the motor. The reasonable design of the motor cooling system can effectively reduce the temperature rise of each component under the premise of minimizing the size of the motor. The cooling system has lower energy consumption, which is conducive to the increase of the power density of the motor. A better cooling system design should take into account the requirements of temperature field and fluid field. While meeting the overall temperature rise requirements, it should also make the cooling liquid have better flow characteristics and lower flow resistance.

6. Conclusions
In this paper, a motor monitoring and cooling system is designed. The mobile phone APP and touch screen (HMI) can realize on-site and remote motor control and monitoring operation status, and cool the motor according to the environment and motor operating temperature. It integrates with the development of industrial Internet of Things technology. The labor cost and labor intensity are reduced, and the operation efficiency and reliability of the motor are effectively improved.

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