A Design of Data Acquisition and Monitoring System for Intelligent Electrical Cabinets

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Abstract

In modern industrial age, the use of electric energy has a higher status in the production and operation of enterprises. In order to ensure the safe and stable operation of the power distribution cabinet in the power distribution room, and to improve the repair accuracy of the staff when an error occurs. This paper designs a monitoring system that collects the internal status data of the power distribution cabinet. This design is based on the STM32 of ARM Company, which can control modules to collect various kinds of data such as voltage and current, temperature and humidity, smoke concentration, etc. Then upload the data to the monitoring cloud platform through 4G Cat1 module. The user can monitor the status on the WeChat applet. When the data is abnormal, the terminal automatically alarms and sends a short message to the control personnel, so that the staff can quickly fix the machine and reduce the economic loss of the enterprise.

Keywords

Smart electrical cabinet, STM32, 4G Cat1.

1. Introduction

With the development of society and the progress of human society, the annual electricity consumption is increasing exponentially. As the tail end of the distribution system of the power grid, the performance of the distribution cabinet has a crucial impact on the safe and stable operation of the local power system [1]. Once there is a problem with the power supply and distribution system, it means that the company may experience a power outage, and the related equipment of the company will stop running and fall into a "paralyzed state".

The internal state data acquisition system terminal of the electric cabinet designed in this paper can obtain the electric energy parameters and non-electrical energy parameters inside the electric cabinet in time. When the parameters are abnormal, there will be a voice alarm, which can make the staff aware of the equipment failure at the first time, increase the repair efficiency, reduce the workload of manual inspection on site, and ensure the safety of enterprise production and people's life.

2. System design architecture

The internal situation monitoring system of the smart electric cabinet designed in this paper is composed of four parts: front-end data acquisition equipment, Internet of Things communication transmission, cloud platform server and user terminal.

The front-end data acquisition equipment is designed to install a data acquisition terminal in each power distribution cabinet to collect internal electric data and environment data. These data are transmitted to the cloud platform server using the 4G cat1 communication module with MQTT protocol [2]. The cloud server communicates with the client through the Internet, and the user can use the WeChat applet to view the internal status of the power distribution cabinet [3]. When data is abnormal,

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users can quickly know through SMS (Short Message Service). The overall architecture of the monitoring system is shown in Figure 1.

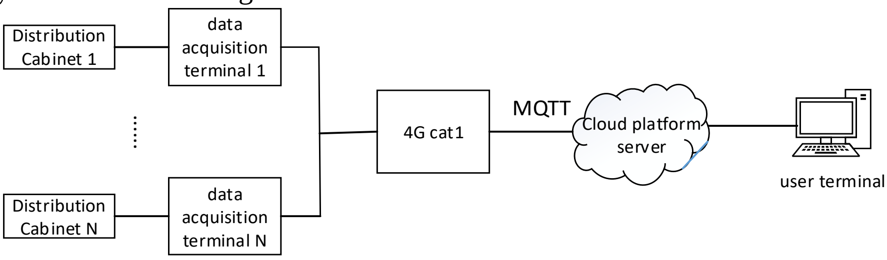


Figure 1: Overall architecture diagram of monitoring system

3. Hardware design

3.1. Choice of microprocessor

Considering the requirement of the high performance, low cost and low power consumption of the design, the data acquisition equipment of this design selects the STM32F103ZET6 chip of ST Semiconductor Company as the microprocessor. Its core is an ARM32-bit Cortex-M3 CPU whose highest operating frequency is 72MHz, and it has abundant I/O ports and communication interfaces [4].

3.2. Terminal Hardware Design Selection

This system selects SUI-101A AC energy metering module to obtain electrical parameters such as voltage, current, active power, etc. The transmission accuracy of current and voltage measured by SUI-101A can reach ultra-high precision of 0.2 class. It is connected with MCU（Microcontroller Unit）through TXD and RXD, as shown in Figure 2.

The module obtains the current and voltage signals from the load line through the built-in current and voltage transformers and sends them to the 24-bit high-precision ADC for processing, and then sends the waveform data to the 8-bit microcontroller to calculate the current, voltage and other parameter values, and finally transmitted to STM32 through the serial port for data analysis.

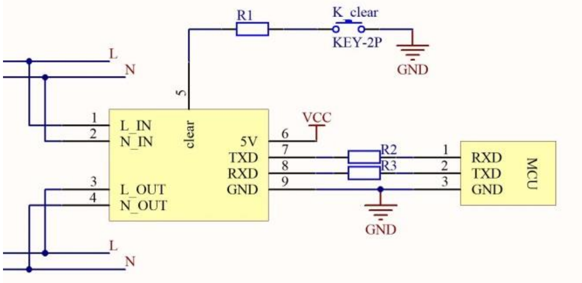


Figure 2: Connection diagram of SUI-101A and MCU

To monitor the temperature and humidity information in the cabinet in real time, the DHT22 sensor is placed to detect and prevent the space in the cabinet from overheating. It is a 16-bit digital temperature and humidity sensor with small size and low price. The humidity detection resolution is 0.1%. In the temperature range of -20℃~+80℃, the accuracy reaches ±2%RH; The temperature measurement resolution is 0.1℃, and the accuracy is less than 0.5℃ in the range of -40℃~+80℃. As shown in Figure 3, OUT is a single bus communication interface, which is connected to the MCU through PA0. When the communication distance is less than 20m, a 5kΩ pull-up resistor is used [5]. The space in the cabinet is small, and a 4.7kΩ pull-up resistor is selected.

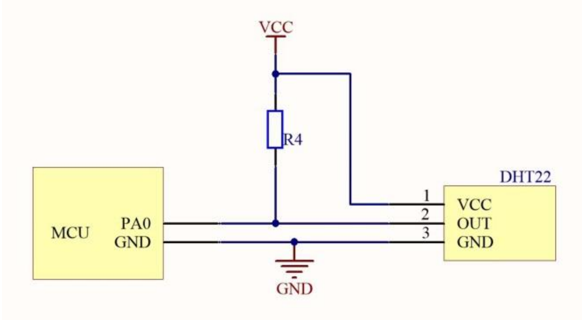


Figure 3: DHT22 sensor interface diagram

Because the inside of the power distribution cabinet is made of plastic cables and wires, a large amount of smoke will be generated when the temperature is too high and the overload is increased to generate sparks or open flames. Therefore, the MQ-2 smoke sensor is selected to collect the smoke concentration signal, the analog signal is converted into a digital signal through the A/D conversion function of the STM32 chip, and the collected voltage value is converted into the smoke concentration by formula transformation. The obtained value is compared with the set threshold to prevent damage to the wire and cable.

When the above data is abnormal, a voice alarm will be issued, and the DY-SV17F intelligent voice module is selected. As shown in Figure 4, when the CON2 pin is set to high level, and the CON1 and CON3 pins are low level, 8 I/O ports can be triggered to play 8 songs. For example, when IO0 is low and the rest are high, the first song is played.

Use an SD card for local storage of information including historical data.

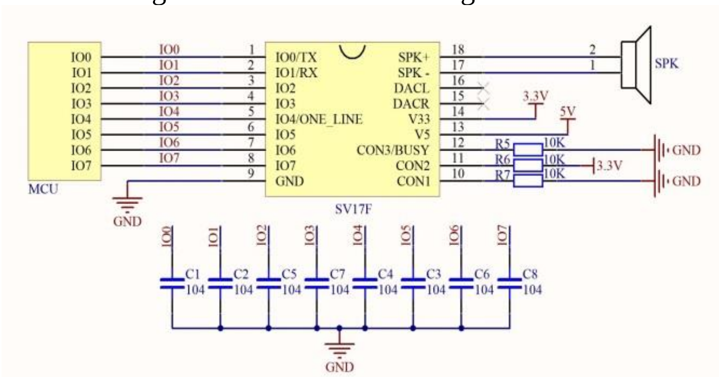


Figure 4: Voice module connection diagram

3.3. Monitoring system terminal data collection requirements standard

The monitoring system terminal data standards are as follows:

1. Electric power monitoring standards. At present, most of the power distribution rooms are 220V or 380V low-voltage power distribution cabinets. The voltage on the primary side can be directly measured, and the current on the primary side needs to be converted into a secondary side measurement current of 5A/1A. This paper takes the rated 220V, 5A, and the power factor of 1.0 as an example to monitor the voltage, current and active power in the power distribution cabinet in real time, and the accuracy error of the measured value is required to be no less than 0.2%.
2. Air temperature and humidity adjustment standards. According to the national standard for low-voltage complete sets of equipment (GB7251.1-2013) [6], the upper limit of the temperature in the cabinet shall not exceed +40°C, and the lower limit shall not be lower than -5°C or -25°C. At the same time, the average temperature difference in one day shall not be higher than +35℃.
3. Smoke concentration standard. The range of detectable combustible gas and smoke of MQ-2 smoke sensor is 100-10000ppm, Therefore, when it is detected that the smoke concentration in the power distribution cabinet exceeds 200ppm, a voice alarm is activated, and a short message

is sent to notify the maintenance personnel to check whether the cables and wires wrapped with rubber skin inside the power cabinet are damaged.

In this experiment, the power distribution cabinet in the school laboratory is selected for testing. To ensure the safety of electricity and personnel, the power data collected in this experiment are normal safety data, and will be further tested in a professional and safe environment in the future; Taking the normal environment as a reference, the temperature and humidity changes are changed by the flame of the lighter and the placement of the ice pack, so as to trigger the abnormal temperature and humidity alarm; To detect the status of the wires and cables in the power distribution cabinet, the burning waste rubber skin is used to simulate a fire and trigger the smoke concentration alarm.

3.4. Communication module

With the rapid advancement of the country's 5G construction, it is the general trend that 2G and 3G will withdraw from the stage [7]. Previously, the domestic market once strongly promoted NB-IoT. However, the 2G network also involves many real-time, mobility, and requires a certain bandwidth transmission capability, and even supports the application scenarios of voice communication capabilities, such as vehicle, mobile payment, industrial interconnection, etc. This is something that NB-IoT, whose uplink and downlink rates are only 100Kbps, cannot satisfy. Therefore, Cat1 for the IoT market stands out [8].

This paper selects ATK-IDM750C module as the communication module. It is a high-performance full Netcom 4G Cat1 DTU product that can hold 4G mobile phone cards. It is applied in occasions with low bandwidth rate requirements with the advantages of low latency and low cost, and can quickly solve the wireless data transmission solution in the application scenario.

It supports connecting to various cloud servers (such as Tencent Cloud, Alibaba Cloud), supports AT commands/SMS, and supports MQTT data transparent transmission. Data transmission is shown in Figure 5. In MQTT transparent transmission mode, serial data can be sent to the MQTT server through DTU.

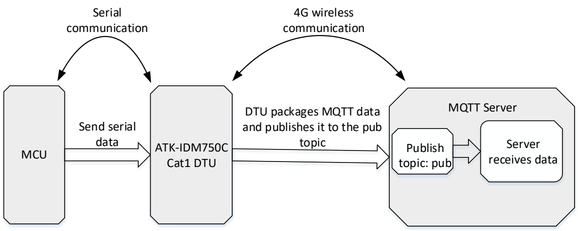


Figure 5: Schematic diagram of data transmission

4. Software Design

4.1. Overall software architecture

The overall architecture of the software design is shown in Figure 6. After the system is powered on, the single-chip microcomputer first initializes the sensor module, obtains the environmental data information inside the cabinet, and compares the collected information with the set threshold. If the data parameters are not within the threshold range, a voice alarm will be sounded immediately, the data will be sent to the cloud platform through the communication module, and the management personnel will be notified by SMS to check the abnormality.

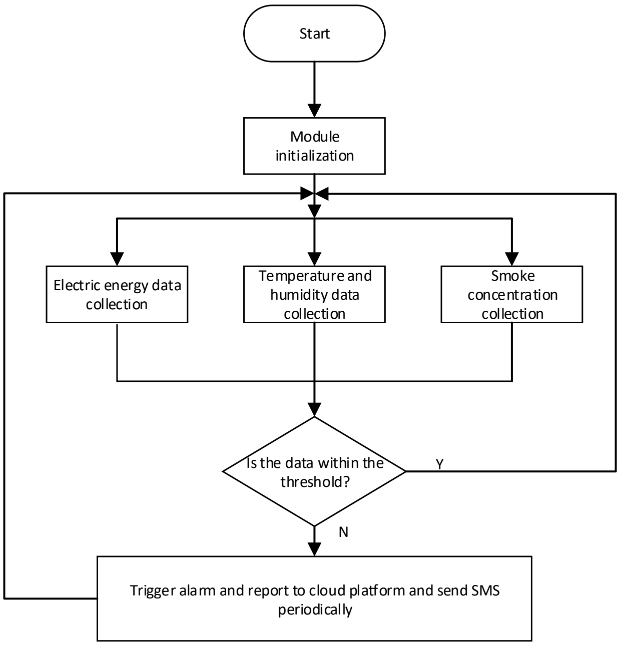


Figure 6: Work flow chart

4.2. Main program design

The compilation of the hardware control program is written using KEIL5 software, which is the best development tool for Cortex-M core processors. In order to make the work between each functional module of the system independent and improve the effective utilization of CPU, the UC/OS-III embedded system is transplanted into STM32 [9]. STM32 occupies the CPU in turn through the algorithm in the UC/OS-III system package, and each function module task is created by the Task_Start initial task, set priorities according to the type of tasks to solve the multi-task scheduling problem, so that people have a kind of CPU to execute multiple tasks at the same time.

4.3. MQTT protocol

MQTT is a low-overhead, low-bandwidth instant messaging protocol. Its biggest advantage is that it can provide real-time and reliable message services for remote devices with very little code and limited bandwidth. MQTT is widely used in Internet of Things, mobile applications, etc.

The MQTT workflow is shown in Figure 7. First, the subscriber subscribes the topic to the server and waits to receive the message; then, the server receives the message published by the publisher and determines the topic of the message. If the message topic is consistent with the topic subscribed by the subscriber, the message is forwarded to the subscriber to realize the delivery of the message from the publisher to the subscriber.

The MCU communicates with the ATK-IDM750C through AT commands, and the message quality QoS selects QoS0 that is distributed at most once. The terminal will collect data to the 4G module through the serial port. The 4G module uploads data every 5 minutes. The PING heartbeat request interval is 1 minute. When there is no message to send, a heartbeat packet [10] must be sent to inform the server that the client is "online".

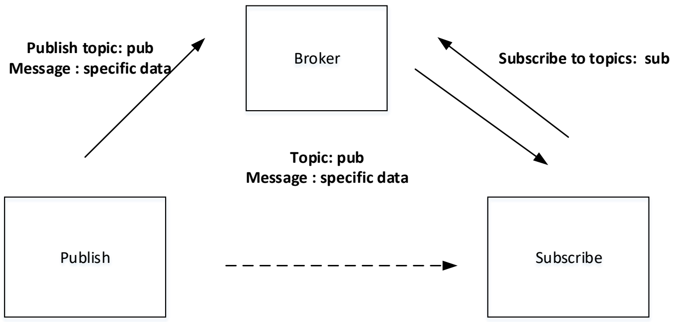
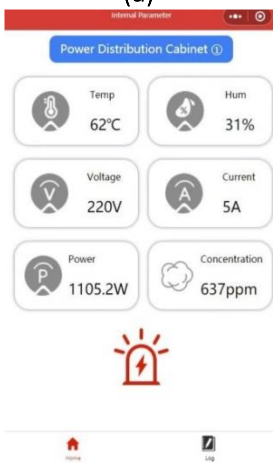


Figure 7: MQTT work flow chart

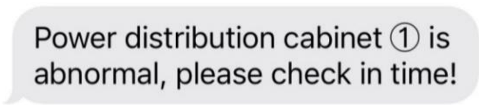
4.4. WeChat applet design

The user terminal can view the data through the WeChat applet. The interface during the test is shown in Figure 8. (a) shows the interface when the data is normal. (b) shows the interface when the smoke concentration exceeds the standard. (c) is the SMS reminder interface received when the data is abnormal.

(a)



(b)



(c)

Figure 8: (a) Data normal interface, (b) Data exception interface, (c) SMS interface.

5. Conclusion

This paper introduces a monitoring system based on STM32 for collecting internal status data of power distribution cabinets. Through the intelligent terminal installed in the power distribution cabinet, the electric data of the cabinet can be automatically collected and analyzed, and the parameters such as humidity and temperature of the environment can be automatically identified. When the collected data exceeds the set limit, the system will trigger an alarm. After receiving the alarm information, the staff can eliminate potential safety hazards in time, which significantly improves the safety of the power distribution cabinet. It can also reduce the workload of on-site manual inspections, increase the work efficiency of staff, ensure the safety of electricity consumption of personnel, and actively respond to the unattended management direction of the power distribution room advocated by the state [11]. The experimental results show that the data detection results meet the standard requirements, and the fault accuracy rate is 100%.

In the future, this design plans to increase the image acquisition function and realize the network long-distance transmission function of the image, which can enable the staff to view the internal status of the power distribution cabinet more intuitively. It is also planned to connect the system to the network alarm device, and notify the relevant departments for rescue as soon as a fire or other major accident occurs to further improve safety.

6. References

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