An Intelligent Management System of Instruments and Equipment Based on Power Line Communication

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Abstract. Instruments and equipment are an important fixed asset of companies and public institutions nowadays, which do not only need to be preserved in value but are also relied on to create more value. However, at present, the management of instruments and equipment is mainly based on manual statistics, sometimes with the help of QR codes to improve the efficiency. With this kind of management method, the statistics collected are oftentimes incomplete and untimely, resulting in repeated investment and a waste of resources. The intelligent management system based on power line communication designed in this solution can collect the device data comprehensively in real-time and form a report, providing data support for the decision-making of the management. Power lines are used as the communication path, so that no extra wire are needed to be deployed and cost can be reduced effectively. The system can comprehensively solve the problems that currently exist in the management of instruments and equipment.

1. Introduction

Nowadays, companies and public institutions have all increased their demands for the fine management of instruments and equipment. Not only the waste of resources caused by the unnecessary purchase of instruments and equipment is required to be avoided, but also the existing instruments and equipment are expected to be tapped of their full potential so as to create greater value. This means the working status, use ratio, energy consumption and location information of the instruments and equipment need to be known in real time, providing reliable data support for fine management. At present, instruments and equipment are mainly managed through manual counting, QR code, and RFID. All of these methods rely on the manual calculation of the various information of the instruments and equipment. These methods not only waste a lot of human resources, but the information collected is inaccurate as well, depriving the management of the necessary real-time information about the working status of the equipment. So, the goal of this system is to use intelligent method to manage the instruments and equipment by automatically collecting and uploading data in a timely and accurate way, saving the labor cost of at the same time. To achieve this goal, there are several traditional methods. One is to achieve communication through a special communication interface. The second is to achieve communication through a wireless network.

By analyzing and comparing the above two methods, it can be seen that the first method is simple in operation, but on the one hand, a communication interface is needed so it cannot be used for devices that do not have communication interfaces. On the other hand, to realize communication between instruments and equipment, communication cables have to be laid, requiring a major renovation of the plant, which will cost a lot. The wireless communication method between the instruments and equipment obviously have some improvement, with no need to lay cables, but on the one hand, most of the equipment do not have wireless communication capability, and on the other hand, the conditions of some factories forbid the use of wireless communication device, which greatly limits the use range. Power line communication technology is a communication method that uses the power line to transmit data signals. This method can enable the full use of the existing power distribution network infrastructure[1]. After connecting the power line to the factory and the office communication is possible when the terminal power is plugged in, so there is no need to deploy new wires, which is convenient, simple and economical. At present, there is no research on the management of instruments and equipment by using power line communication technology. Therefore, this paper is written to propose an intelligent management system that uses power line (PLC) as a communication route to collect the information of instruments and equipment.

2. Design thinking of the intelligent management system of instruments and equipment based on power line communication

The intelligent management system of instruments and equipment based on power line communication uses the power line communication technology and uses the power distribution network as the communication channel. The system can help to collect the information of instruments and equipment, and transmit the information by relying on Ethernet. The system consists of three parts, an adapter, a concentrator and a software platform. Fig.1 is its overall system block diagram. Each instrument is equipped with an adapter that does not interfere with the working process of the electrical equipment and does not affect the use of the electrical equipment. Each adapter is equipped with a power line communication unit and a measuring unit for collecting the power consumption information of the equipment, such as voltage, current and power, and pass the information onto the concentrator through a power line. Each concentrator is equipped with a power line communication unit and a network transmission unit. On the one hand, it can manage a certain number of adapters through the power line, and on the other hand, it can transmits the parameters, such as the voltage, current and power of the instrument, to the software platform through the Ethernet communication. The software platform then can use the information and calculate the working status, working time and energy consumption of each instrument and provide the data to the management, providing accurate data for sound decision-making.

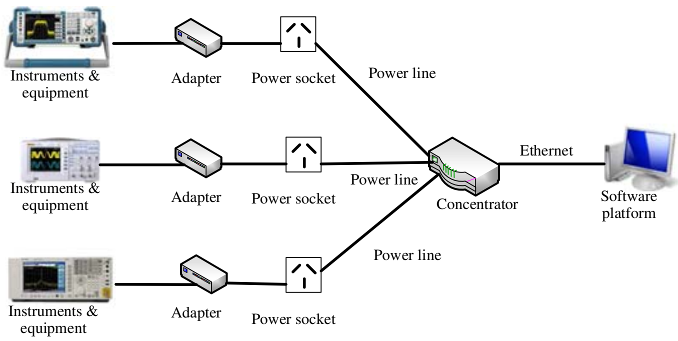

Figure 1: Overall system block diagram.

In this solution, power line communication is the key technology. Despite of its apparent advantages, the power line is not originally designed as a communication channel. Due to the numerous types and quantities of power equipment, the channel is not very suitable with great noise and obvious multipath effect [2,3] . To solve this problem, Orthogonal Frequency Division Multiplexing (OFDM) is designed to be better at anti-multipath effect and anti-interference. OFDM can flexibly distribute information to different carrier frequency bands[4], thus having a better robustness in overcoming narrowband interference and frequency selective fading. Besides, when combined with forward error correction code, it is highly good at overcoming impulse noise interference[5]. Therefore, this solution selects HZ3001 and HZ3011 chips produced by Hang Tian

Zhong Dian Technology Company to realize broadband power line communication. The chips integrate flexible and reliable PLC MAC, PLC PHY based on OFDM modulation and demodulation, cost-effective analog front end and various peripheral interfaces, including UART, SPI, I2C, GPIO and so on. It can provide power line signal transmission rate up to 10Mbps, with the frequency range between 100KHz to 30MHz.Its subcarriers can support modulation methods such as BPSK, QPSK and 16QAM. It also supports fast automatic networking and can support up to 4000 terminal ad-hoc networks.

3. Design of the concentrator

The concentrator is the bridge for data communication between the principal computer and all the monitoring units. It is also used for managing the adapter mounted on the concentrator. When the principal computer needs to access the adapter's data, it first sends the access command to the concentrator through the Ethernet. After the concentrator analyzes the principal computer's command, it goes on to read the data of each adapter through the power line, and then sends the copied data to the principal computer for analysis and decision-making.

3.1 Hardware design of the concentrator

The concentrator is composed of a power management unit, a main control unit, a power line communication module, an Ethernet communication module, a data storage function circuit and so on, as shown in Fig.2. The main control unit is the core part, which is realized by the STM32 minimum functional circuit. It controls the Ethernet communication module and make the module receive and analyze a command, and then controls the power line communication module to make it transmit the command to the adapter through the power line communication. In this solution, the power line communication adopts the aerospace power company. The power line communication in this solution is realized by the HZ3001 chip produced by Hang Tian Zhong Dian Technological Company. The power management unit is used to convert the alternating current into a voltage suitable for the circuit, for example, from 220V to 12V, 12V to 5V, and 5V to 3.3V. Flash is used to store instructions and the acquired data, and the serial port-USB interface is used for debugging.

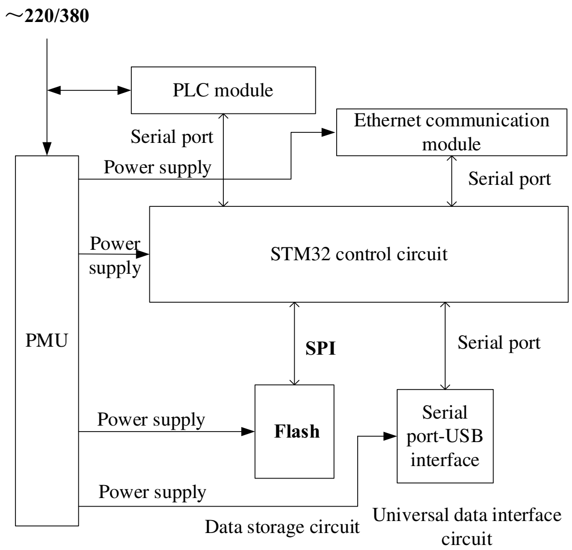

Figure 2: Hardware block diagram of the concentrator.

3.2 Software design of the concentrator

After the concentrator is powered on, it will wait for the command given by the software platform to start the collection of data. After receiving the command, it will convert the frame format of the command, send the data collecting command to the specified adapter, and then collect the adapter's data in real-time. To each PLC adapter, the data collection command can be sent for three times at most. Once data frames are returned by the PLC adapter, the data collection command will stop being sent out, and the data will be uploaded to the software platform. If no data frames are returned by the PLC adapter after the command is sent out for three times, the adapter will be deemed as being offline, and this data will be uploaded to the software platform.As shown in Fig.3

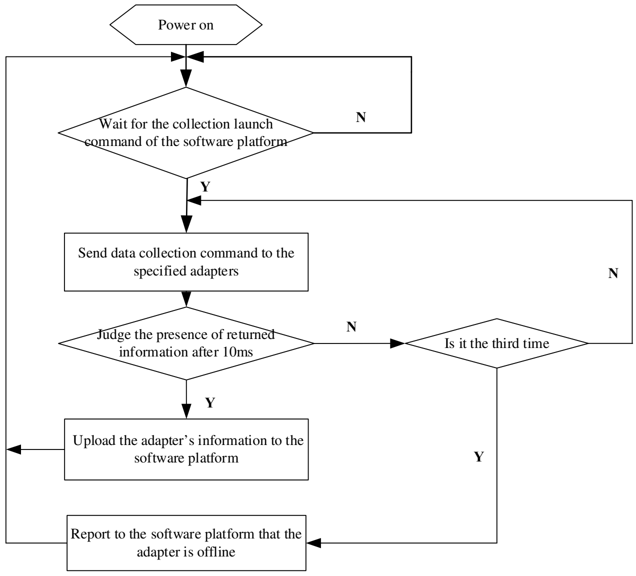

Figure 3: Flow chart of the software of the concentrator

4. Design of the adaptor

The adapter is an interface that enables the communication between the concentrator and the equipment. On the one hand, it can receive and execute the instructions of the concentrator through the power line. On the other hand, it can collect the parameters of an equipment such as its voltage, current and power, and can transmit the parameters to the concentrator through the power line. At the same time, in order to avoid the loss of the collected data, the data will be stored in an internal memory on the basis of power line data transmission.

4.1 Hardware design of the adaptor

The hardware circuit of the adapter is mainly composed of three parts: a main control MCU and the memory module, a measurement module, and a power line communication module. The main control MCU is the core part of the device, which controls the other three modules through interfaces and realizes the data transmission function. The MCU used in this solution is the STM32F103VR8 of the Cortex-M3 of the ARM series produced by ST company. The measurement module uses CS5463 metering chip for data acquisition, a chip widely used in China's single-phase meters.The solution uses FLASH memory MX25L25635 chip to store offline data. To realize the communication between the PLC adapter and PLC concentrator, the HZ3011 wideband carrier chip produced by Hang Tian Zhong Dian Technological Company is adopted as the power line communication module. The hardware structure block diagram is as shown in Fig.4.

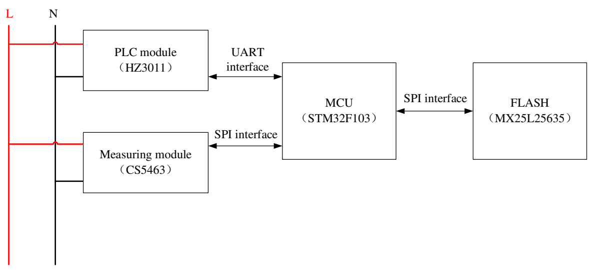

Figure 4: Block diagram of the working principle of the adaptor's hardware.

4.2 Design of the software of the adaptor
When the PLC adator is powered on, the working process of its software is as follows in Fig.5.

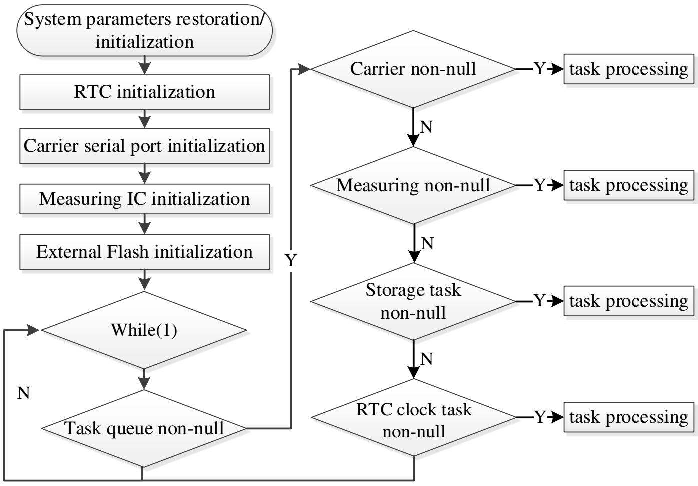

Figure 5: Working process of the adaptor's software.

After power-on, the system will recover the parameters, initialize the external IC, and query tasks, including: interaction data initiated by the carrier module, measurement, acquisition and calculation task, storage task, RTC clock task, etc.

The main program queries the task queue cyclically. When there is a valid task in the task queue, the task will be executed. Among the tasks, the carrier task refers to the data interaction task between the adapter and the carrier module, including the address search after the powering-on, uploading corresponding data to the concentrator according to the concentrator's command, rewriting the working current's threshold and the standby current's threshold, etc. Measurement tasks include the 500ms polling data collection and measurement, and the obtain of voltage, current, power, active power, and power factor data to provide data for storage tasks and carrier tasks. Storage tasks include the storage of event data and status data. And RTC clock tasks are responsible for maintaining the system time.

5. Design thinking of the software platform
The software platform is the initiator of commands and the presentation end of data. When the user needs to collect the data of a certain terminal, a command can be sent. After receiving the command, the adapter will transmit the data to the concentrator through the power line, and the concentrator will transmit it to the software platform in the principal computer through the Ethernet for analysis and decision-making. In this system, the user can directly collect the power consumption, voltage and current parameters of each terminal instrument, and the management can pinpoint the instruments with higher energy consumption through the power consumption data. With this information, energy use and emission reduction goals and cost-saving goals can be made to create greater value for the company.

In addition to power consumption, the system can also collect the working voltage and current of instruments, but this is not the data that the user concerns. The user needs to know the working status and use ratio of instruments, so as to further tap their potential and create more value. The software platform is based on the data about the current, and can judge the working status and use ratio by setting threshold. As shown in Fig.6, if the standby current of a device is 0.5A and the working current is 5A, the standby current threshold can be set at 0.3. A and the working current threshold at 4A. When the current is greater than 0.3 A and less than 4A, it will be considered to be in the standby state. If the current is greater than 4A, it will be considered to be in working state. The formula for the calculation of daily use ratio η is as follows.

η =working hours/8 hours*100% (1)

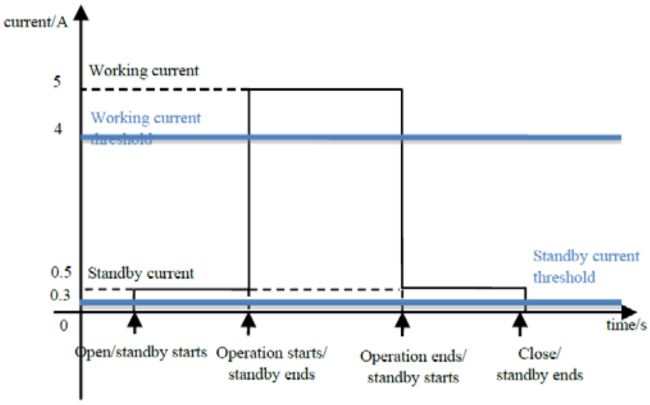

Figure 6: Diagram of the device's working status.

The adapter is an interface that enables the communication between the concentrator and the equipment. On the one hand, it can receive and execute the instructions of the concentrator through the power line. On the other hand, it can collect the parameters of an equipment such as its voltage, current and power, and can transmit the parameters to the concentrator through the power line. At the same time, in order to avoid the loss of the collected data, the data will be stored in an internal memory on the basis of power line data transmission.

6. Application effect

The system has been initially realized and has operated for a short period of time. The various performance indicators all can meet the requirements and have achieved the expected goals. Fig.7 is the system's homepage, Fig.8 is the current value of a certain instrument collected by the system, from which the use ratio of the instrument can be calculated. Fig.9 shows the use ratio statistics of some typical instruments. From this figure, It can be seen that the "high speed temperature variation test chamber" has a high use ratio and is basically in a saturated state. If the task amount continues to increase, new test equipment needs to be purchased, otherwise the test task will be piled up. Fig.10 shows the total energy consumption statistics of the unit. Fig.11 shows the energy consumption statistics of the "high speed temperature variation test chamber". It can be seen that the energy consumption of the test chamber is relatively high. So, to reduce costs and increase energy efficiency, it is better to start from this instrument. Through the investigation, dry running of the instrument is found out. After the treatment, the situation is reduced, saving more than 1000 degrees of energy consumption and bringing economic benefit to the company.

Figure 7: Homepage of the software platform.

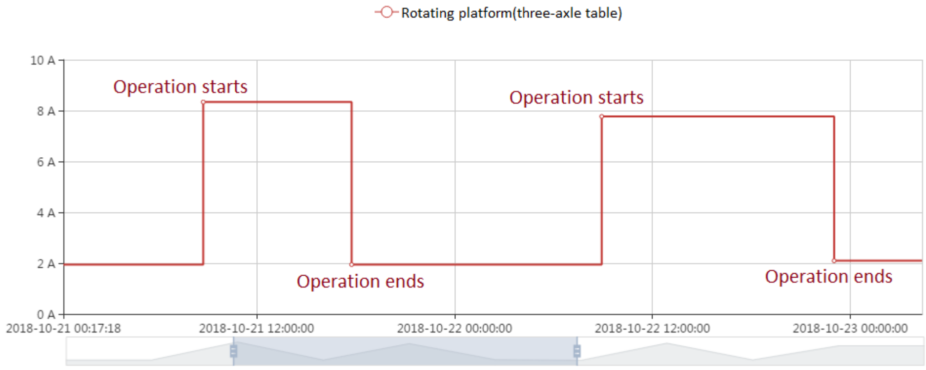

Figure 8: Current value of an instrument.

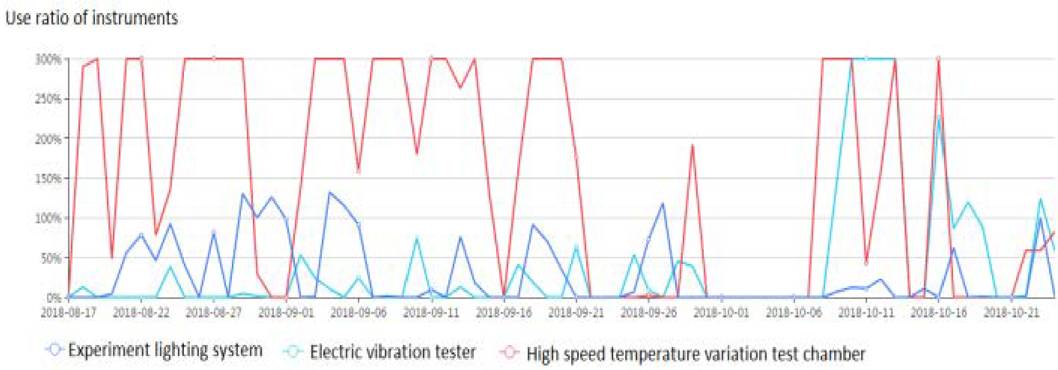

Figure 9: Use ratio of instruments.

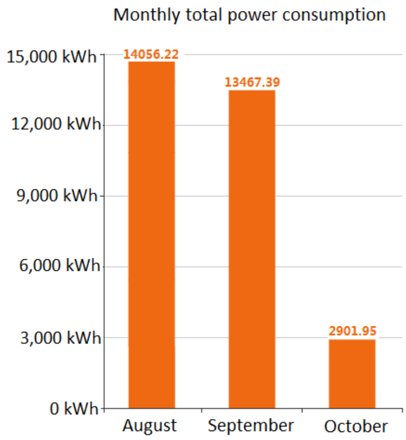

Figure 10: Total energy consumption

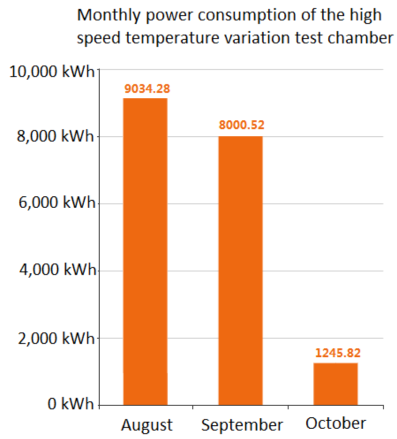

Figure 11: Power consumption of the test chamber

7. Conclusions

Based on the power line communication technology, the solution realizes the intelligent management of instruments and equipment, and can provide users with energy and use ratio information in real time and accurately. It can provide data support for users to reduce costs and increase efficiency and tap the full potential of instruments and equipment. With the solution, no new deployment of wires are needed, the cost is low and the efficiency is high. It has been running for some time, and the indicators all meet the expectations and has achieved the purpose of design.

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