

# Research and Design of the Data Center Electrical Energy Monitoring System

Jie Huang<sup>1, a</sup>

<sup>1</sup>College of Mechanical and Electronic Engineering, Hezhou University, Hezhou, China, 542899

<sup>a</sup>huangjie0773@163.com

**Keywords:** Data center; Electric energy monitoring; Zigbee; CC2530

**Abstract.** In order to accurately monitor the electrical energy consumption of the electrical equipment in the data center, combined with Zigbee wireless communication technology and electric energy metering chip, a data center electrical energy monitoring system is studied and designed. The system uses Zigbee technology to build the network. It can accurately measure the electrical energy consumption of the electrical equipment in the data center. The system can also monitor the working status of the electrical equipment in the data center. Hardware design and software design of the system are introduced in this paper. The system has been tested. The results show that the system has good stability and convenient operation. The system can accurately monitor the electrical energy consumption and working status of the electric equipment. It has great application value.

## Introduction

With the development of society, the data center has been widely deployed in the world. As an effective means of transmitting, computing and storing data information on the internet network, the data center has been used by many organizations. The data center to support the operation of the internet service in the cloud search, cloud computing and social networking and other aspects. There are a lot of electrical equipments in the data center. In order to ensure the normal operation of the electrical equipment, the data center needs to consume a large amount of electric energy. However, there is a big waste of energy consumption in the data center which leads to the loss of a large number of electrical energy in the data center. How to reduce the electrical energy consumption of the data center and build a green data center have been getting more and more extensive attention. The electrical energy monitoring systems on the market usually monitor the electrical energy consumption of the entire data center. Because the system did not monitor the electrical energy consumption of the electrical equipment, so the system could not grasp the value of the electrical energy consumption of the electrical equipment in the data center. It can not be used for the electrical energy consumption of the electrical equipment to develop effective energy saving measures. In order to build a green data center of energy saving, low consumption and environmental protection, this paper studies and designs a data center electrical energy monitoring system. The system is organized by Zigbee wireless network. It can accurately monitor the electrical energy consumption of the electrical equipment in the data center. At the same time, the system can accurately monitor the working status of the electrical equipment in the data center.

## System Scheme Design

**Overall System Structure.** The system consists of the electric energy monitoring node, router, coordinator and the monitoring terminal. The overall structure of the system is shown in Fig. 1. The electric energy monitoring node, router and coordinator uses Zigbee technology to build the network. The monitoring terminal communicates with the coordinator through the serial port. The Zigbee network supports star topology, tree topology and mesh topology. In this system, the tree topology is used to construct the Zigbee network. The electric energy monitoring node, router and coordinator are all using CC2530 chip.

**Electric Energy Monitoring Node.** Electric energy monitoring node is used to monitor the

electrical energy consumption of the electrical equipment in the data center. At the same time, it monitors the working status of the electrical equipment in the data center. The electric energy monitoring node is composed of an electric energy consumption measuring circuit, a voltage detecting circuit, a current detecting circuit, a keyboard, a relay control circuit, a socket and a LCD display. The structure diagram of electric energy monitoring node is shown in Fig. 2.

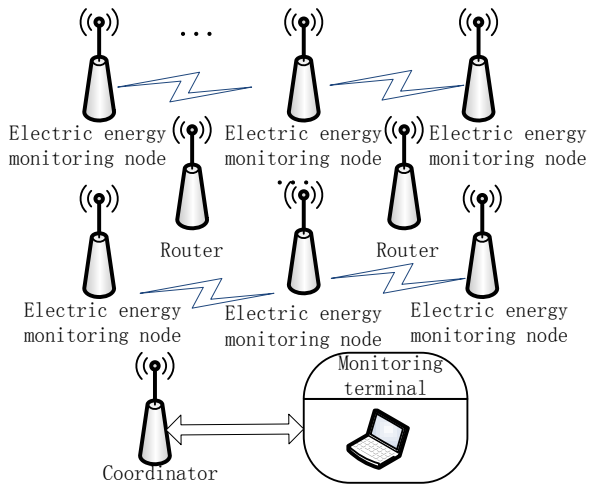


Figure 1. Overall system structure

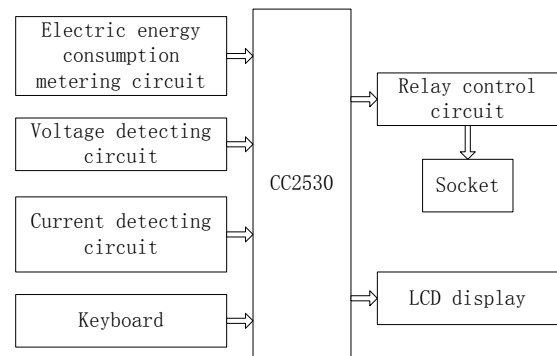


Figure 2. Structure diagram of electric energy monitoring node

## System Principle and Hardware Design

**Principle of Electric Energy Measurement.** The electric energy metering chip BL6503 is used in the electric energy measuring circuit. The BL6503 chip is a single phase bidirectional electric energy metering chip. It uses over sampling and digital processing technology in the design. It has the advantages of high precision and stability. The chip is especially suitable for the electric energy measurement of single phase two wire. The principle of electric energy measurement is that the voltage and current of the electric equipment can be multiplied to obtain the instantaneous power of the time. The electric energy consumption of the equipment can be obtained by integrating the instantaneous power according to the time integral. The voltage of the electric equipment is shown in Eq. 1. The current of the electric equipment is shown in Eq. 2. The phase difference between voltage and current is  $\varphi$ . Instantaneous power is shown in Eq. 3.

$$u(t) = U \cos(\omega t) \quad (1)$$

$$i(t) = I \cos(\omega t + \varphi) \quad (2)$$

$$p(t) = u(t) \times i(t) = \frac{UI}{2} \cos \varphi + \frac{UI}{2} (\cos \varphi \cos 2\omega t - \sin \varphi \sin 2\omega t) \quad (3)$$

According to the Eq. 3, it is known that the instantaneous power signal contains DC signal and AC signal. The DC signal is  $(\frac{UI}{2} \cos \varphi)$ . The AC signal is  $(\frac{UI}{2} \cos \varphi \cos 2\omega t - \frac{UI}{2} \sin \varphi \sin 2\omega t)$ .

Firstly, a low pass filter is proposed to obtain the DC signal in the instantaneous power. Secondly, the DC signal is integrated by time. Finally, the numerical value obtained by the integral operation is the electric energy consumption value of the electric equipment. However, if the voltage signal and current signal contain DC signals, it will affect the accuracy of the measurement value of the electric energy consumption. The voltage signal is shown in Eq. 4. The current signal is shown in Eq. 5. There are DC signals of  $U_1$  and  $I_1$ . Instantaneous power signal is shown in Eq. 6.

$$u(t) = U \cos(\omega t) + U_1 \quad (4)$$

$$i(t) = I \cos(\omega t + \varphi) + I_1 \quad (5)$$

$$p(t) = u(t) \times i(t) = \frac{UI}{2} \cos \varphi + U_1 I_1 + \frac{UI}{2} \cos \varphi \cos 2\omega t + U_1 I \cos \omega t + U_1 I \cos(\omega t + \varphi) \quad (6)$$

If the voltage signal and the current signal contain DC signal, the DC signal of the instantaneous power signal is  $(\frac{UI}{2} \cos \varphi + U_1 I_1)$ . Due to the influence of the DC signal by  $(U_1 I_1)$ , the accuracy of the measurement value of the electric energy consumption can be affected. In order to improve the accuracy of measurement of electric energy consumption, it is necessary to remove the DC signal from the voltage signal and the current signal in the calculation of power.

**Electric Energy Metering Circuit.** The electric energy measuring circuit is shown in Fig. 3. The manganin resistance is the role of the current signal into voltage signal. V1P pin is the positive input pin of the current sampling signal. V1N pin is the negative input pin of the current sampling signal. The voltage between the V1P pin and the V1N pin input range is  $(\pm 660mv)$ . V2P pin is the positive input pin of the voltage sampling signal. V2N pin is the negative input pin of the voltage sampling signal. The voltage between the V2P pin and the V2N pin input range is  $(\pm 660mv)$ . The BL6503 chip through the SCF, S1 and S0 to set the working mode. The role of G0 and G1 is used to adjust the system gain of the current channel. BL6503 chip converts active electric energy into frequency signals. The frequency signal is output from the F1 port and the F2 port in a low level. The output frequency signal is shown in Eq. 7.

$$F = \frac{U(v) \times U(i) \times F_z \times gain \times 8.34}{V_{REF}^2} \quad (7)$$

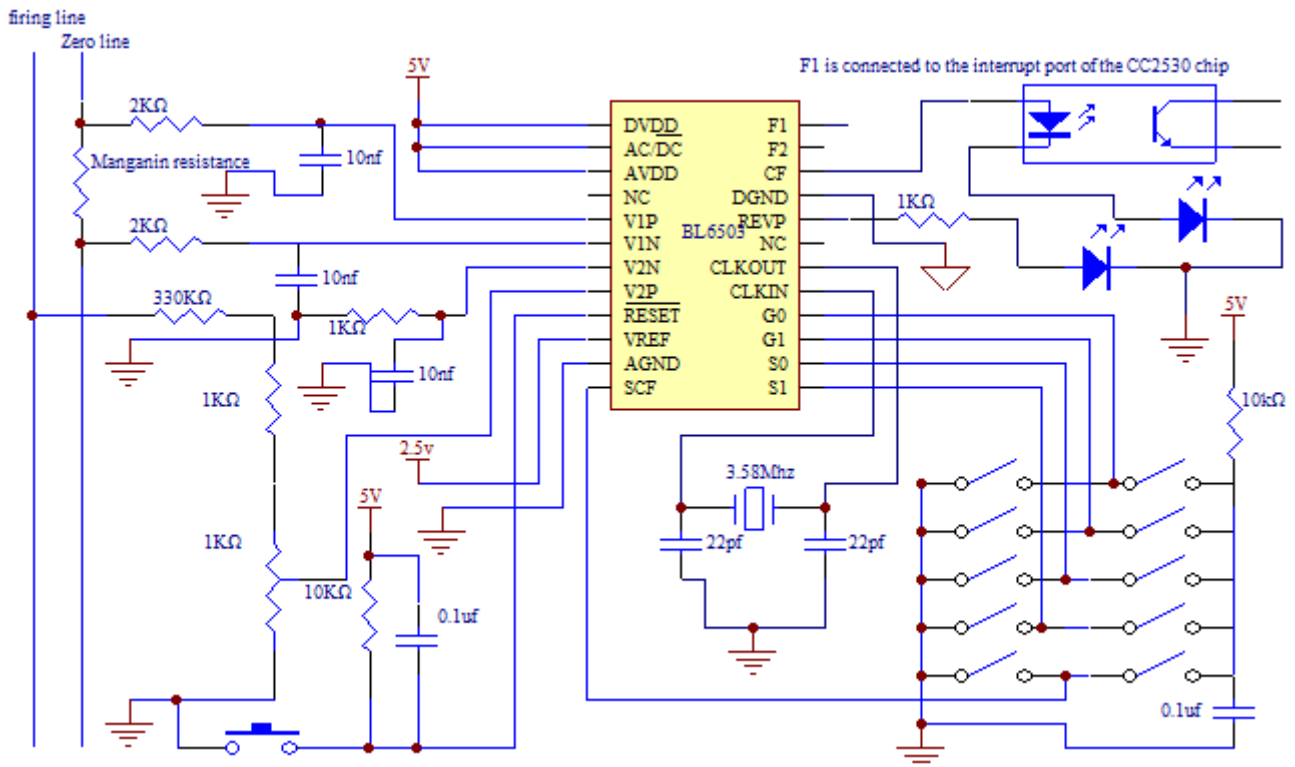


Figure 3. Electric energy metering circuit

**Current Detecting Circuit.** The function of the current detecting circuit is to detect the current of the electric equipment. The current detection circuit is shown in Fig. 4. It consists of a current sampling resistance, a voltage collecting and amplifying circuit, a voltage dividing circuit and a rectifying circuit. Manganin resistance is the role of the current acquisition of electrical equipment. The function of the first level amplifying circuit is to collect the voltage on the sampling resistor and amplify the voltage. The function of the rectifying circuit is to rectify the signal. A voltage signal from the rectifier is sent to the CC2530 chip A/D conversion interface.

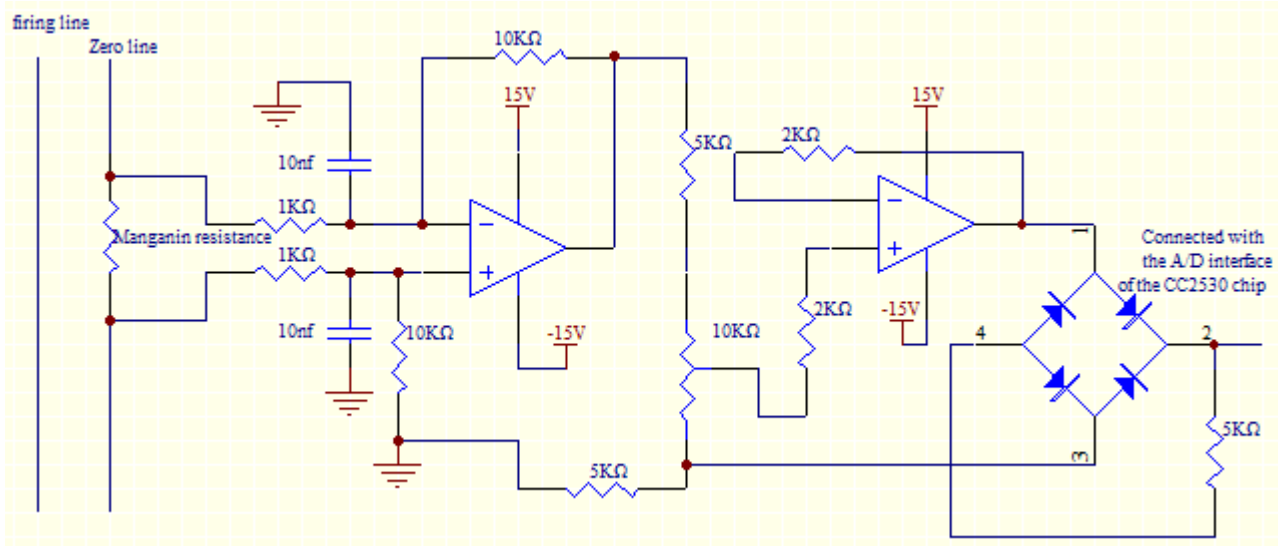


Figure 4. Circuit detection circuit

## System Software Design

**Monitoring Terminal Software Design.** The monitoring terminal can manage the electric equipment in the data center. The power ratings, equipment number and electric energy consumption value of the electric equipment are stored in the monitoring terminal. The monitoring terminal needs to register the first use of the electrical equipment in the data center. The monitoring terminal receives the data of the electric energy monitoring node through the Zigbee wireless network. Data need to be analyzed, updated, stored and displayed by the monitoring terminal. If the working voltage or working current of the electric equipment is not normal, the monitoring terminal sends out the alarm signal and cuts off the power supply of the electric equipment through the wireless network. The number of electrical equipment and type of electrical equipment in the data center has variability. In order to accurately monitor the electrical energy consumption of the electric equipment in the data center, the electric equipment consumption of the electric equipment in the data center can be managed by the monitoring terminal. The monitoring terminal transmits the electric energy consumption value of the electrical equipment to the electric energy monitoring node through the wireless network. The administrator can view the working state of the data center and the electric energy consumption of the data center in real time through the monitoring interface of the monitoring terminal. The administrator can carry out the remote management of the electrical equipment in the data center through the monitoring interface. Monitoring terminal uses C# language programming. The flow chart of the program design of the monitoring terminal is shown in Fig. 5.

**Software Design of Electric Energy Monitoring Node.** Data center has a lot of electrical equipment. The number of equipment and the type of equipment may be changed in the future. Socket can be connected to different electrical equipment. In order to accurately measure the electrical energy consumption of the electrical equipment in the data center, all of the electrical equipment will be unified in this system. All the electrical equipment has a unique device number within the data center. When the electric equipment is connected with the socket, the power supply

of the electric equipment is controlled by the keyboard input device number. Electrical energy monitoring node sends the device number of the electric equipment to the monitoring terminal.

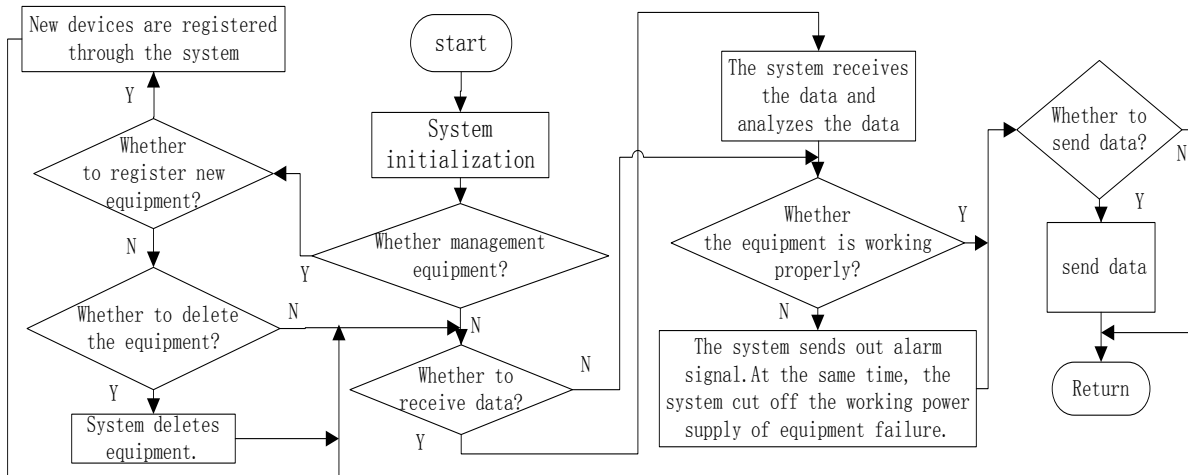


Figure 5. Monitor terminal program design flow chart

The power rating of the electric equipment and the power consumption value of the electric equipment are transmitted back to the electrical energy monitoring node by the monitoring terminal. Electric energy monitoring node monitors the power consumption of the electrical equipment. The working voltage and the working current of the electric equipment are detected by the electric energy monitoring node. If the working voltage or working current of the electrical equipment is not normal, the power supply of the electrical equipment will be cut off. The monitoring data of the electric energy monitoring node is transmitted to the monitoring terminal through the Zigbee wireless network. At the same time, the electrical energy monitoring node receives the data of the monitoring terminal through the Zigbee wireless network. Power monitoring node program uses C language programming. The program design flow chart of the electric energy monitoring node is shown in Fig. 6.

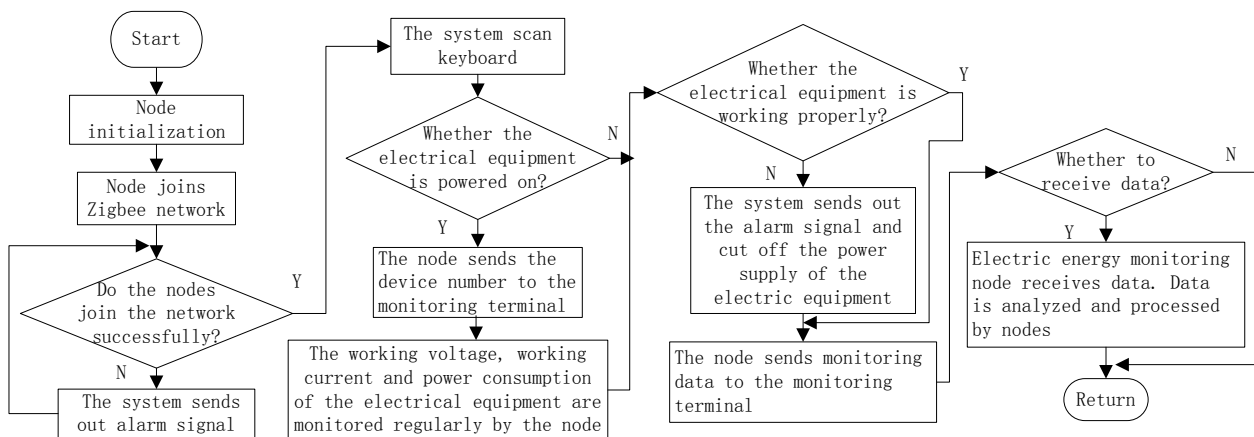


Figure 6. Flow chart of program design for electric energy monitoring node

## System Test

According to the design requirements and control requirements of the system, the system is installed in a data center. The parameters and performance indexes of the system are tested. 20 electrical energy monitoring nodes, 5 routers and a coordinator are installed in a data center. The monitoring terminal communicates with the coordinator through the serial port. At different time, the system was tested. Test data are shown in Table 1 and Table 2.

The test data from the monitoring voltage can be known that the maximum value of the relative error is 0.13% and the average value of the relative error is 0.098%. The test data from the electric energy consumption value can be known that the maximum value of the relative error is 0.12% and the average value of the relative error is 0.07%. The system can accurately monitor the electric energy consumption of the electrical equipment in data center. It can also manage and monitor the electrical equipment. Parameters and performance indexes are in line with the design of the system.

Table 1 Test data of the electric energy monitoring node

Device number	Monitoring voltage/measured voltage [V]	Monitoring current/measured current [A]	System measurement value/meter measuring value (electric energy consumption) [degree]	Voltage / current /electric energy consumption (relative error)
01	221.3/221.5	4.510/4.495	36.51/36.55	0.09%/0.11%/0.1%
05	220.2/220.5	2.270/2.268	18.00/18.01	0.13%/0.089%/0.06%
12	219.7/219.5	0.00/0.00	0.00/0.00	0.09%/0.00%/0.00%
16	222.5/222.8	6.730/6.721	38.60/38.65	0.13%/0.12%/0.12%

Table 2 Test data of the monitor terminal

Device number	Power rating [W]	Electric energy consumption of the same day [degree]	Alarm status	Socket status
01	1000	12.3	No alarm	Connected
05	500	5.8	No alarm	Connected
12	700	0.0	No alarm	Disconnected
16	1500	16.7	No alarm	Connected

## Conclusion

A data center electric energy monitoring system is designed and implemented in this paper. The system can accurately monitor the electric energy consumption, working voltage and working current of the electrical equipment in the data center. The electrical equipment in the data center can be managed and monitored by the system. When the equipment is working abnormally, the system sends out the alarm signal. At the same time, the working power supply of the electrical equipment is cut off by the system. The electrical energy consumption of the electrical equipment in the data center can be grasped by the system. According to the electrical energy consumption of electrical equipment, a reasonable energy saving measures can be formulated. The system has the advantages of convenient operation and good stability. It has a good application prospect.

## References

- [1] X. Li and X.H. Jiang: Journal of Computer Science, Vol. 38 (2015) No.10, p.1976. (In Chinese)
- [2] X.Q. Wang, Y.J. Ou and N.L. Huang: *Design and Implementation of ZigBee Wireless Sensor Network* (Chemical Industry Press, Chinese 2012), p.92.
- [3] L.M. Sun, J.Z. Li, Y. Chen and H.S. Zhu: *Wireless Sensor Network* (Tsinghua University press, Chinese 2005), p.85.
- [4] Y. Dong, Q. Yang and W.J. Yan: Application of Electronic Technology, Vol. 38 (2012) No.9, p.78. (In Chinese)
- [5] L.H. Sun and H. Wang: Modern Electronic Technology, Vol. 39 (2016) No.4, p.35. (In Chinese)
- [6] H.Y. Zhang and N.T. Huang: Electrical Measurement & Instrumentation, Vol. 22 (2015) No.19, p.36. (In Chinese)

- [7] Z. Jiang and D. Liu: *ZigBee Technology and Practical Training Course* (Tsinghua University press, Chinese 2014), p.85.
- [8] J.Z. Du and H. Liu: *ZigBee Technical Principle and Actual Combat* (Mechanical Industry Press, Chinese 2015), p.120.
- [9] H.Y. Zhang and N.T. Huang: *Microelectronics & Computer*, Vol. 32 (2015) No.10, p.137. (In Chinese)
- [10] J.Y. Lin and Y. Li: *Electronic Design Engineering*, Vol. 23 (2015) No.18, p.130. (In Chinese)