The Design and Application of Intelligent Electrical Outlet for Campus's Electricity Saving and Emission Reduction

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***Abstract*— The electrical energy waste phenomenon on colleges and universities' campuses is very severe. The Internet of things provides technology guarantee for energy saving, and intelligent electrical outlets are important components of colleges and universities' campus electricity management system which can be designed to different schemes according to different situations. This paper introduces the design and application of intelligent electrical outlet, which can measure effectively electricity data and control power supply line on-off, cut off electrical appliance's power at nonessential time interval, thus achieves the goal of electricity saving and emission reduction. This intelligent outlet is also safe, reliable, anti-electromagnetic radiation and anti-jamming.**

***Index Terms*—Electricity saving and emission reduction, Colleges and universities' campus, Electricity consumption, Electricity management system, Intelligent electrical outlet**

I. INTRODUCTION

Energy saving and emission reduction refers to reduced energy waste and reduced exhaust emission. Since Zhejiang Province of China wants to achieve business making people rich and innovation making strong province in, energy consumption problems can not be neglected. The National Development and Reform Committee(NDRC) requires that Zhejiang province's energy consumption should drop 18% per unit of GDP during the 12th Five-Year Plan which is a period of rapid industrialization, urbanization and modernization for Zhejiang. With the economic gross expanding continuously, there is a serious problem is the shortage of resources and the lack of environment carrying capacity. As the excellence in Chinese economy entities, Zhejiang once again faces the contradiction of economic social development and environmental protection, and it also faces the heavy pressure of the energy saving and emission reduction.

Since May 2011, the electricity situation is very serious within the scope of Zhejiang province. It is predicted that the Zhejiang province's highest electricity load demand will reach 50,000,000 kilowatts during summer peak period. But it can only meet 46,500,000 kilowatts by its own and purchased electricity, there is still lack of 3,500,000 kilowatts, especially 5,000,000 kilowatts under extreme climate conditions. Among them, about 70% of electricity comes from thermal power, and thermal power depends on coals as the main energy. If thermal power plant produces 1 degree of electricity with generating 500g carbon dioxide, the total carbon dioxide emissions of the above electricity consumption can reach 25,000,000 tons. It is a very large amount, and it will make a difference to the environment. Therefore, energy saving and emission reduction brook no delay.

Recent years, with the rapid development of higher education, the scale of colleges and universities has been expanding unceasingly since 1999, then they have the rapid increases in energy consumption. So colleges and universities have become one of the major energy consumers, and their energy expenditure increased nearly 30% year after year. Relevant data of Ref. [1] shows that campuses' annual electricity consumption total quantity accounts for 5% of national total electricity consumption, and its expense surpasses 80,000,000,000 Yuan. The campuses' electricity consumption in unit area is 4 times higher than ordinary households' consumption per unit area. Furthermore, energy consumption in unit building area is more than the world's leading energy superpower, the United States. Currently there are various 78 colleges and universities in Zhejiang Province: 30 ordinary undergraduate colleges, 4 ordinary college and 44 higher vocational colleges. The sum of students is 909,900. So, the college and university's campuses also face important energy saving and emission reduction because they exist serious phenomenon of wasting the electricity.

Therefore, energy saving has been put on the agenda, the colleges and universities should take various measures to achieve energy saving and emission reduction targets. In addition to building the idea of saving energy, establishing the perfect management mechanism and implementing the responsibility system, the introduction of advanced science and technology is a kind of effective energy saving techniques. This can avoid the above waste of electric energy mostly by another way. On June 10, 2011, Zhejiang governor

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Zushan Lu pointed out: "Continue to deepen the technology progress, increase the energy saving and emission reduction in new technology, new process, new products, new equipment to popularize strength" in television and telephone conference of energy saving and emission reduction work. As the latest scientific research positions, colleges and universities should also provide the latest energy and saving emission reduction technology to provide strong technical assurance for Zhejiang economy sustainable development.

Rapid developing technology of the Internet of things makes the intelligent power consumption technology further mature and perfect. Intelligent power consumption technology is a terminal portion of smart grids. And its typical representatives include: intelligent bidirectional meter, smart appliances, intelligent electrical outlets, intelligent electrical terminals, intelligent electricity consumption management information systems and interactive electricity technologies [2]. Among them, intelligent bidirectional meter in the electric power industry has been developing more mature. Intelligent appliances, intelligent electrical outlets, intelligent electrical terminals are now the most swift and violent developing fields by third enterprises. All kinds of products are uneven qualities which some are good and some are bad. Intelligent electricity consumption information systems and the form and the control strategy of interactive electricity software systems are the high-en core parts of the intelligent power consumption technology, especially the communication among heterogeneous networks. The equipments and technologies can together form intelligent power management system of colleges and universities to monitor and control the electricity consumption and reduce the waste of electric energy. For example, a typical college's intelligent power management system includes: gateways, intelligent electrical outlets (including communication module), guide rail type electric meters (including communication module), air conditioning controllers, electric water heater controller of intelligent electrical terminals. Gateways are connected to system network service center through the Ethernet network, and upload data to the system service center. The administrator can log in the webpage of service center, view the situation of the electricity consumption and control the system remotely through PC or mobile phone.

Based on analyzing the current situation of the power consumption, electricity saving and emission reduction, this paper studies a suitable kind of intelligent electrical outlets for achieving good electricity saving effect, thus we can reduce the energy consumption and emission reduction by using it.

II. THE PRESENT SITUATION OF ELECTRICITY CONSUMPTION AND ENERGY SAVING ON CAMPUSES

Before studying electricity saving technology, we first need to simply analyze the present situation of electricity consumption and energy saving of colleges and universities' campuses. With constant expansion of colleges and universities, there are different campus areas and different power consumption situation, so we should treat these situations separately. The existing energy saving measures is insufficient and ineffective. We should know this, and then improve and enhance, thus we truly achieve national requirements for energy conservation and emission reduction goals.

A. Waste electricity situations

There are two large areas on campuses, such as students' apartment area and teaching area mainly, where energy consumption is different. In addition the students' apartments exists waste water, gas, heater phenomena, the teaching area and apartment area exist the following electricity waste phenomenon:

(1) The multimedia teaching building: Electric lamps, fans, teaching equipment and appliances are always turned on even if there is no person.

(2) Teachers office building: Computers, water machines, air conditionings are open as usual.

(3) Laboratory building: All kinds of laboratory equipments and computers' power waste phenomena are very common. Many computers are also working especially in the morning or the afternoon after first two classes. But only a few students could shut down the computer and turn the electricity off, so this causes much electrical energy waste.

(4) Students apartment block: Some students use high-powered electrical equipment. That is unsafe and it maybe cause fire disaster; And a few dormitories exist stealing electricity phenomenon.

(5) The electricity consumption of multimedia computer peripherals is often ignored by us.

According to materials provided by Shanghai energy conservation association [3] : A ordinary outlet's power in no load is 1.9 W; a host standby power consumption is 4.81W after the power is off; a display standby power consumption is 30W when it is not in use; and a printer standby power consumption is 12W. In Zhejiang water conservancy and hydropower college, for example, there are 22 administrative departments and 11 teaching department. We assume that each administrative department has two printers, and each teaching department at least has five network printers. If we don't switch off all equipments' power when they aren't at work time, there are total 400 computers working 6 hours with full load and other 18 hours standby. These computers and peripheral equipments' electricity consumption in the standby situation is as follows:

$$((1.9\text{W}+4.81\text{W}+30\text{W})\times 400+12\times(22\times 2+11\times 5))\times 18\times 365 \approx 104279\text{kW} \quad (1)$$

According to 0.538 Yuan per KWH in Hangzhou, multimedia computers and printers' standby electricity consumption is about a total of 56,102 Yuan one year.

Above data is only for the most basic configuration of multimedia computers. In fact, various colleges and universities have different electric equipments such as other computer peripherals and office scanner, graph plotters, multimedia classrooms and speech controllers, speakers, video monitors and so on. If we add these

equipments to calculate, there will be much more electricity waste.

B. Current situation of electricity consumption and emission reduction

At present, there is the energy saving committee in every college or university. But many problems also exist in energy saving work as follows[4] : management is lax and all kinds of waste energy phenomenon exists for the long time; Energy saving regulations isn't normative and effective energy saving management and incentive policy is scarce; Energy saving measures are deficient and management and supervision isn't in place; The good and bad staffs are intermingled in energy saving management; Energy saving propaganda and education isn't up to breadth, depth and strength.

Now, most colleges and universities' power supply management is a extensive management. Generally there are three modes of management[5]:

1) No special personnel management;

2) Using timer switch turns on or off the power supply according to work and rest schedules;

3) A assigned staff switches on or off the power supply with floor according to work schedules and weather conditions.

These extensive management modes aren't enough to solve thoroughly above all kinds of waste electricity phenomenon. In the global perspective, scientific literature [6-8] introduce some measures and methods including reforming the management mode, technology, equipment for electricity saving. But the investment cost of these methods is too high.

In addition to setting up the energy saving consciousness, these are kinds of effective energy saving technologies-establishing and improving the management mechanism, implementing the responsibility system, and introducing advanced technology. In these technologies, the intelligent electrical outlet is a kind of effective electricity-saving monitoring controller.

III. REQUIREMENTS ANALYSIS OF THE ELECTRICITY SAVING CONTROL

According to the special environment of colleges and universities in Zhejiang province, there are different waste electrical situations in different areas of a campus, so supervisory control objects are also different. A common campus is composed of the teaching area and the living area.

A. Main equipments in teaching area

The Teaching area includes teaching buildings, laboratory blocks, the library and office buildings mainly. In this area, those following equipments should be monitored and controlled: indoor floodlights and corridor lightings, multimedia teaching equipment in teaching building; all kinds of laboratory equipments and computers in labs; air conditionings and automatic water machines in the library and office buildings.

B. Others in the living area

In this area, these following equipments should be monitored and controlled: High-power electrical appliances in apartments; instead, high-power electrical appliances in the canteen where the intelligent electrical outlet mainly measures electricity data and analyses them for high-power electrical appliances working safely and stably.

Therefore, the intelligent electrical outlets aren't the same in different places. They are mainly designed to monitor different appliances, once they detect those power of appliances is switched on in idle time, then automatically cut off the power of electrical equipments.

Ⅳ. THE CAMPUS ELECTRICITY MANAGEMENT SYSTEM

International Telecommunication Union (ITU) issued "Internet Reports 2005, The Internet of Things ", which put forward the concept of the Internet of Things. The main goal of the Internet of things is to solve interconnection between things and things, people and things, people and people. The Internet of Things and the traditional Internet are different things. The interconnection between people and things refers to the connection by using general-purpose devices. The interconnection among people refers to the communication of people not depending on PCs. With the technology research and application on the Internet of things, problems which traditional Internet can not solve can be solved by the Internet of things. The information technology development of a new generation offers the possibility of "Smarter Planet". It has the more thorough perception and measurement, the more comprehensive internetworking, and the more in-depth intelligence. From a technical perspective, the Internet of things is to use Radio Frequency Identification (RFID) and the wireless data communication technology based on computer networking. According to the agreed protocols, it takes radio frequency identification equipments, infrared sensors, global positioning systems, laser scanners and other sensors and equipments to connect any people and goods with Internet for the exchange of information and data communication. Thus it can realize intelligent identification, location, tracking, monitoring and management of the new generation network technology. Obviously, the Internet of things provides technical support platform for colleges and universities' electricity saving and emission reduction.

Recently the latest colleges and universities' campus electricity management system is a new kind of developing electricity saving and emission reduction technology. Its main purpose is to remotely measure and control lamps, split air conditionings, water heaters and other electrical equipments through the modern computer technology and communication technology. According to above analysis, there are two typical campus's electricity consumption management systems, one for the living area, another one for the teaching area.

A. Campus's electricity management system in the living area

A kind of the typical campus power management system in the living area will be introduced next. This system is mainly designed for centralizing monitor of room lights, air conditioning, electric water heater, measurement and control management. And it provides intelligent management services of electricity for the campus, which include the database hosting, the measurement of electricity meters, the analysis of equipments' electricity, the fault alarm, and remote control, etc.

Users should install related products including the gateway, intelligent electrical outlets (including communication module) or guide rail type electric meters (including communication module), air conditioning controllers, water heater controllers, etc. Then those devices are linked together to the system network service center through Ethernet. The gateway will upload the data to the system service center. Finally administrator login the webpage of the system service center to view and control those devices through the PC. The accessing method is shown as the following Fig. 1.

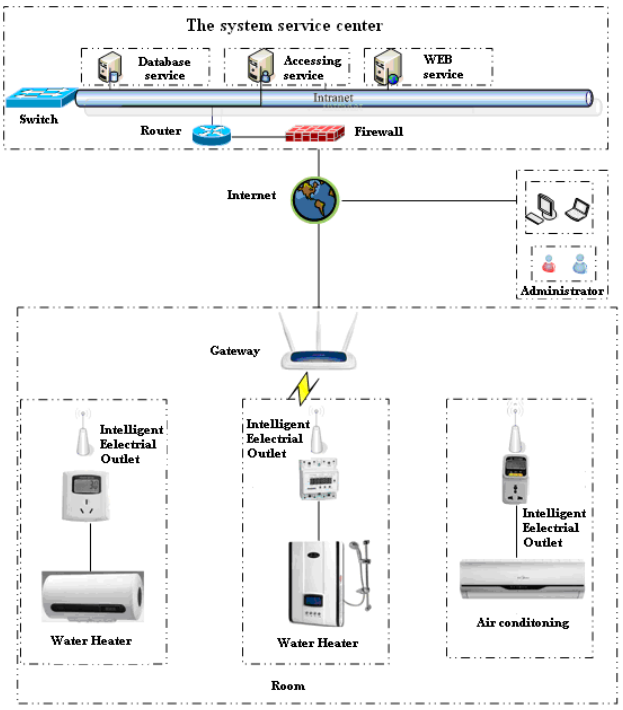

Figure 1. A typical campus power management system

The system hardware devices mainly are consisted of computers, gateways, intelligent electrical outlets, guide rail meters, split air conditionings (air conditioning control module), electric water heaters. And the control center is mainly consisted of software, the database and the Web service. Other related equipments include the firewall, routers, servers and switches.

1. System schemes

According to the different situation and different budget of various colleges and universities, there are different schemes for electricity monitoring and management. Generally there are three types which are simple scheme, medium-sized scheme and intelligent scheme. Obviously the first one is very simple, and the last one is complicated relative to both front schemes. Functions of intelligent electrical outlets are more powerful in the last one.

1) The simple scheme

The main center equipment is the gateway in this scheme, which collects electricity information from intelligent electrical outlets and guide rail electric meters, and then transmits data to the system service center. It is as shown in table I.

TABLE I. THE SIMPLE SCHEME

No.	Device	Functions	Communications
1	Gateway	1. Providing downlink channels 2. Sampling data of intelligent electrical outlet regularly	UP: accessing system service center by Ethernet Down: accessing Intelligent electrical outlets by PLC/RS485 communication
2	Intelligent electrical outlets	Measurement of air conditioning, electric water heater of electricity	Uplink to the gateway by wireless communication
3	Guide rail electric meters	Measurement of forking air conditioning, electric water heater of electricity	Uplink to the gateway by wireless communication

2) The medium-sized scheme

Besides above functions, the gateway can remotely control intelligent electrical outlets in this scheme, and intelligent electrical outlets and guide rail electric meters can turn on or cut off the power supply. It is as shown in table Π.

TABLE II. THE MEDIUM-SIZED SCHEME

No.	Device	Functions	Communications
1	Gateway	1. Providing downlink channels 2. Sampling data of intelligent electrical outlet regularly 3. Providing remote control intelligent electrical outlets	UP: accessing system service center by Ethernet Down: accessing Intelligent electrical outlets by wireless communication
2	Intelligent electrical outlets	1.Measurement of air conditioning, electric water heater of electricity 2.Control the power supply on-off	Uplink to the gateway by wireless communication
3	Guide rail electric meters	1.Measurement of forking air conditioning, electric water heater of electricity 2.Control the power supply on-off	Uplink to the gateway by wireless communication

3) The intelligent scheme

The gateway in this scheme is still the core equipment which collects electricity information from intelligent electrical outlets and guide rail electric meters, and then transmits data to the system service center. But intelligent electrical outlets and guide rail electric meters are not only receiving remote signals to turn on or cut off power supply, but also monitoring the electricity consumption and switching off the power by themselves. That is as shown in table III.

TABLE III. THE INTELLIGENT SCHEME

No.	Device	Functions	Communications
1	Gateway	1. Providing downlink channels 2. Sampling data of intelligent electrical outlet regularly	UP: accessing system service center by Ethernet Down: accessing Intelligent electrical outlets by PLC/RS485 communication
2	Intelligent electrical outlets	1.Measurement of air conditionings electric water heater of electricity 2.Control the power supply on-off 3. Control the air conditioning(Supporting mainstream air conditioning type) through the docking	Uplink to the gateway by wireless communication
3	Embedded guide rail electric meters	1.Measurement of forking air conditioning, electric water heater of electricity 2.Control the power supply on-off	Uplink to the gateway by wireless communication

2. System functions

The campus power management system divide into three modules: data acquisition (DAQ) and forwarding support, system business, business applications.

1) Data acquisition and forwarding support

Service center exchanges data with gateways, sends command to gateways, receives the alarm information from gateways. It can remotely control intelligent electrical outlets and control the relays on-off.

2) System business

It is included that basic parameter maintenance, authority management system, system security check, system operation log.

3) Business applications

It is mainly included that the file maintenance, equipment maintenance, the data view, the dynamic power capping, the electricity consumption statistics and analysis, the energy efficiency analysis, the abnormal investigation one by one.

Because the paper space is limited, above functions are not described here in detail.

B. Campus's electricity management system in the teaching area

The hardware devices of campus's electricity management system in the teaching area are similar to those in the living area. In addition to devices mentioned above, there are wall-mounted wireless human body sensors, the intelligent control terminal, web cameras, etc.

The software is also similar to that one in the living area. But controlled objects are different, the program is a little changed.

Compared with the living area, the controlled objects are different in the teaching area. So there are two general schemes. The first scheme is simple one, and the second scheme has more complex and more powerful functions.

1. Scheme 1

As shown in Fig. 2, some devices are equipped together and achieve the following functions in this scheme.

1) Intelligent control terminals (simple version) are installed, which have the intelligent control and wireless communication functions.

2) There are plenty of wall-mounted wireless human body sensors (depending on room size), which once detect the human body and then send information to intelligent control terminals.

3) Wireless intelligent switch controllers are packed in air conditioning's outlets. They can communicate with intelligent control terminals by the wireless way, and receive intelligent control terminal's instructions. They also can stop, power off, open, start the air conditioning.

4) Wireless intelligent control switches are adapted from original ordinary switches of floodlights or other critical parts. These switches receive intelligent control terminals' instructions by wireless communication, power on and power off the floodlights. These switches also can be controlled by touching switches directly.

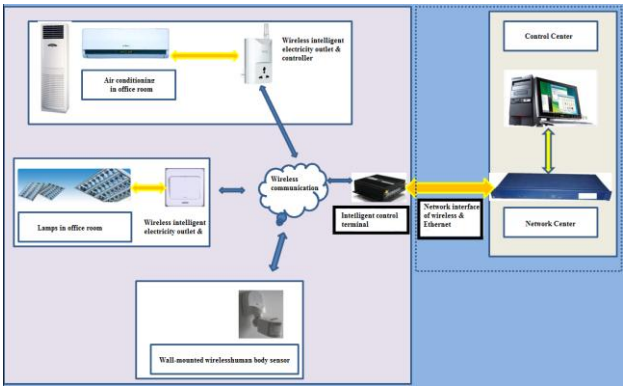

Figure 2. The structure schematic diagram of the scheme 1

2. Scheme 2

In addition to the equipments and functions mentioned above as scheme 1, there are added web cameras (webcam) in the scheme 2. They monitor and connect with intelligent control terminals through the Ethernet, and relay to the network center. These webcams have far infrared, night vision and motion sensors, support capturing human images, and support transmitting alarms by E-mail. Those are as shown in Fig. 3.

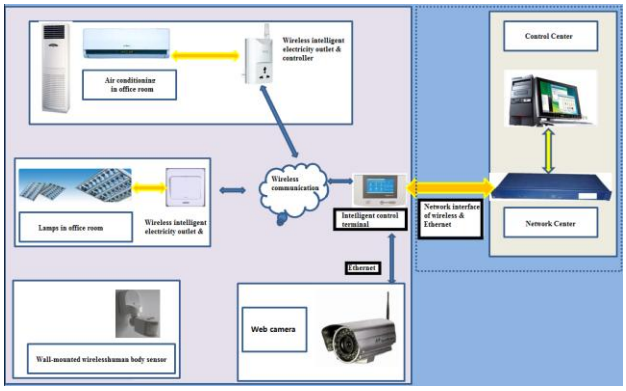

Figure 3. The structure schematic diagram of the scheme 2

According to the different electricity situations between the living area and the teaching area, the intelligent scheme in living area and scheme 2 with webcams in teaching area are better than others. So this paper study how to design a kind of intelligent electrical outlets for colleges and universities' campus based on these two schemes.

V. INTELLIGENT ELECTRICAL OUTLET

The intelligent electrical outlet is designed to satisfy the requirement of intelligent power management.

A. Functions of intelligent electrical outlet

The traditional power socket is only a power distribution. Besides this function, intelligent electrical outlet is one important component of intelligent power supply management system. It has a intelligent chip in the socket, and this intelligent chip recognizes various electrical equipments, real-time monitors equipments which the situation of the power, records electricity data, transmits data to the gateway controller, receives instructions from the distance through the wireless network, cuts off electrical equipments for reducing energy consumption. There have been intelligent electrical outlets of different functions on the market at present. Those outlets mainly can be divided into the following categories: leakage protection type, timing type, main circuit control type, remote control type, measurement type and etc [9,10]. Papers [9-14] introduce various different designs of intelligent electrical outlet. But those outlets just provide a single protection, monitoring or control and those products' function is relatively single, which is difficult to realize informatization and remote control and can't meet requirements of the intelligent campus's power saving.

Based on analyzing the above needs of the colleges and universities, the intelligent electrical outlet should include the functions as follows:

1) Data acquisition and monitoring. It can acquire the power supply line current, voltage, power consumption, the parameters from light intensity and infrared sensor.

2) Data transmission function: It can use the wireless local area network which is free, good real-time, high transmission rate, low cost, safe and reliable, and transmit these data to the gateway. How the outlet timely and accurate responses the gateway is to ensure that electrical equipments work in apple-pie order, and that is very important.

3) Data analysis and display function: It can process, store, manage, display those collected data. Through monitoring voltage, current, and power consumption, it can analyze the situation of the load such as the operation of electric power, standby power consumption etc. to provide the reference.

4) Control function: Through the relay, the outlet can control the electric power supply on-off.

5) The auxiliary function: Those include in data query, parameter setting, energy saving preset program, monitoring alarm, rights management etc.

6) System extensibility and compatibility functions: Because the intelligent electrical outlet will be developed on the basis of original power system, so how to connect to the original system must be considered, that is, the system redundancy is worthy of consideration. And we also should give consideration to the increase of other functions for the future.

B. The design of the intelligent electrical outlet

The hardware principle diagram of the intelligent electrical outlet is as shown in Fig. 4. The entire system contains microprocessor as the core, power signal measurement module, power conversion module, power control module and communication module, etc.

1. Microprocessor

The microprocessor is the core component of the intelligent electrical outlet. It is responsible for the calculation of the measured signal, processing, communication and control. Therefore, we choose the integrated mixed-signal system level MCU (C8051F020), which has a VDD monitor, the watchdog timer to prevent crash inside the chip.

2. Signal measurement module

The input voltage and the current are first through the divider resistance, manganese pieces of copper converted to weak signal. Then after a special measuring chip (ATT7030A), the produced electricity data are input to MCU for follow-up processes.

3. Power control module

If the monitoring data by MCU exceed limit value thresholds, MCU controls the relay close or open and thereby cuts off the power supply of electrical equipments. Generally the capacity of the chosen relay is higher than the maximum power load. This module should be matched with the discharging circuit which is mainly composed of a capacitance and a diode to absorb the instant reverse current and to avoid instant high voltage and high current affecting the circuit.

4. Communication module

This module is mainly responsible for communications between intelligent electrical outlet and the gateway controller. At present a small local wireless networks is a good choice, e.g. ZigBee. Its communication rate and reliability meet the system requirements.

5. Power conversion module

This module mainly converts 220V AC voltage to internal system needed DC voltages, such as + 5V, + 3.3V, provides the MCU system chip and the circuit

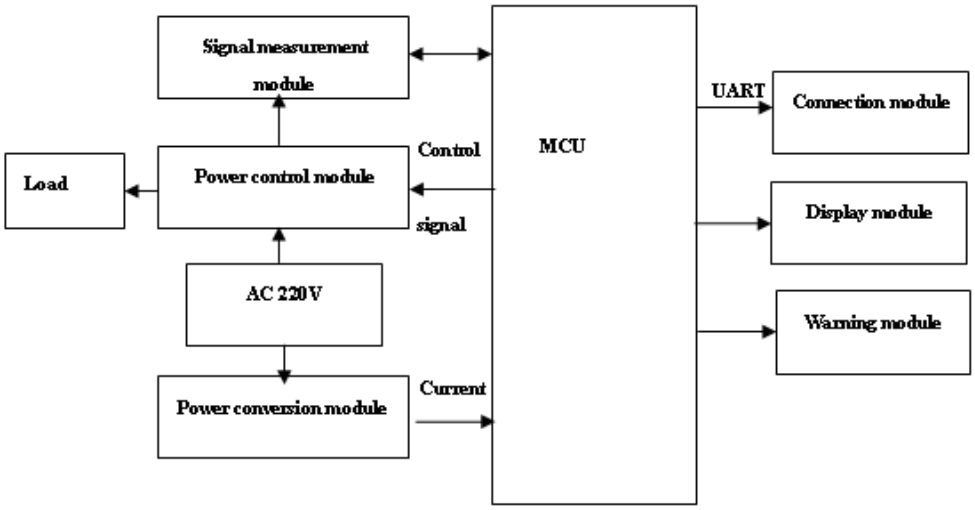

Figure 4. Intelligent electrical outlet functional block diagram

inside, etc. Common integrated voltage chip 7805 can be achieved for purpose.

6. Display and alarm module

Display module is mainly to check the current electricity measuring data at any time, such as the voltage and the power value. Finding data exceeding the thresholds, MCU sends the command to the alarm module for sound and light alarm.

The main program of intelligent electrical outlet mainly includes monitoring and processing measurement signals, communicating and controlling the power, etc. When the monitoring data is more than the threshold, MCU issues a warning signal and controls the sound and light alarm, then sends data to the gateway controllers by the communication module. The receiving part of the communication module uses the interrupt mode, responds rapidly gateway controllers order, and controls the relay on-off through the interface. So the power of electrical equipments is shut off at unnecessary work intervals.

VI CONCLUSION

This paper studies the intelligent electrical outlet for energy conservation and emission reduction in new technology, and provides a good reference of high efficiency energy saving and emission reduction for other domestic colleges and universities. Through the experimental comparison, using the intelligent electrical outlet can save electricity energy 10% ~ 40% or so. Along with the electrical equipment components getting aging and standby energy consumption increasing, electricity saving rate will be further improved by using the intelligent electrical outlet. Thus, it meets the energy saving policy of high efficiency and low cost, and can produce good economic benefits and social effects.

To sum up, the intelligent electrical outlet is a kind of the energy saving and emission reduction in colleges and universities' campus. The intelligent electrical outlet for domestic universities and enterprises and households' electricity monitoring, energy conservation and emission reduction are significant.

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