



**Energy Saving of Central Air-Conditioning and Control System**  
**Caseb Study: Nanchang Hongkelong Supermarket**

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Abstract

In China, with the rapid development of economy, the resources are consumed very seriously. Compared with the developed countries, China's energy consumption for unit GDP production is more than 6 to 10 times and the energy consumption for unit product production is 50% higher than in the developed countries. Therefore, China is increasing emphasis on energy conservation and is also increasing the awareness of energy saving and environmental protection.

In energy saving measures, the one that reduces energy consumption of the central air conditioning is very important. Because in industrial and commercial buildings, central air conditioning system is a very important part of infrastructure and it is widely used. It takes a large proportion in industrial production and the total daily energy consumption of buildings. In industry, central air-conditioning energy consumption accounts for over 40% of the total energy consumption.

In this thesis, the problem and the cause of the problem were found according to the research of the specific practical problem of the traditional energy saving system. Based on the theory of intelligent building management system (IBMS) and energy-saving central air-conditioning inverter, a means of vector control can be adopted to achieve the integrated use of the technology and a solution to improve the Central Air Conditioner equipment and improve HVAC energy saving control system can be found.

In this thesis, it was studied how to reduce the central air-conditioning energy consumption, and also it was a case study about improvement of Nanchang HKLS air conditioning system. This case study shows the practical design and practical improvement of the project can be known and it is also shown the energy saving result by economic analysis is also presented.

Keywords

Central Air Conditioning, HVAC, Energy Saving, CACS, Inverter

Confidentiality

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## 1 Introduction

Because of worldwide energy crisis, the construction of industry development has brought a great impact. There are increasingly widespread attention for the rational use of energy and new energy development. [1]

In China, with the rapid development of economic situation, the resources are consumed very seriously. Compared with the developed countries, China's energy consumption for unit GDP production is more than 6 to 10 times and the energy consumption for unit product production is 50 % higher than in the developed countries. Therefore, China is increasing emphasis on energy conservation and is also increasing the awareness of energy saving and environmental protection. Saving energy, reducing production and office costs become one of the main ways to improve the market competitiveness in many enterprises. [1]

In energy saving measures, the one that reduces energy consumption of the central air conditioning is important. To improve the living environment, there are many places such as apartments, villas and residential areas that have begun to use the central air-conditioning. Especially more and more central air-conditioning systems are installed in commercial office buildings, factories, supermarkets and other built-up areas. In industrial and commercial buildings, central air conditioning system is a very important part of infrastructure and is widely used. It takes a large share in industrial production and the total daily energy consumption of buildings. In industry, central air-conditioning energy consumption accounts for over 40% of the total energy consumption. In commercial buildings, the mechanical and electrical equipment and lighting take more than 80 % of energy consumption, and central air-conditioning energy consumption has accounted for about 60 % of this energy consumption. [1]

How to reduce the central air-conditioning energy consumption but still ensuring a comfortable environment has become an issue which is focused by both scientists and

engineers. So, around the world, there a lot of manpower, material and financial resources are put to research the energy-saving buildings and higher requirement for energy conservation of the building HVAC system are also put forward. Also this is a main focus of this thesis. [1]

## **2 The status and development of the energy saving of HVAC system**

Because of great economic and social benefits, central air-conditioning energy-saving technology has more and more widespread attention. The central air-conditioning energy-saving technology is studied by many companies and scientific research workers and it has experienced a number of technical innovations. [2]

### **2.1 Background**

- The first-generation of energy-saving technology [2]

The main way that the first generation of energy-saving technology is reforming the energy-saving system of central air-conditioning water pump is by using frequency conversion control technology which makes a single pressure or temperature control. With the pressure control, it increase 10 % to 30 % energy-saving; with the temperature control, it increases 40 % energy-saving. It usually accounts for 5 %~10 % in the whole energy-saving of central air conditioning system.

- The second-generation of energy-saving technology [2]

The second-generation of energy-saving technology has the intelligent control on the basic of traditional inverter technology which is using advanced computer software processing, modular control with inverter technology and the collection and processing of multi-point technology. This way the control system can keep pace with changes in temperature and can have dynamic adjustment of the actual load. Then main unit of air conditioner can reach 10 %-30 % energy saving and water system can reach 60 %-80 % energy saving. Thus, it reaches about 20 %-40 % energy saving in the whole machine system.

Starting from the second-generation technology, control software processing has become the core technology of energy saving system. There are many new technologies which are applied to the energy-saving device in a wide range such as an expert system, a fuzzy system and an optimized control. The core module for control, which is suited for the actual needs, becomes a key of research and implements the technology of central air-conditioning energy-saving. The traditional PID only applies to single-variable linear control system and is powerless for multi-variable and multi-disturbance of central air-conditioning unit control system.

There is also another development direction for central air-conditioning energy saving which is used in variable flow control in the central air-conditioning system. During operation of variable flow system, the flow is controlled by adjustment of PID parameter and set pressure technology. The flow loop of various branches changes in the load of external environment change. This does not only ensures the comfort of air-conditioning system, but also achieves purposes of energy-saving.

- The third-generation of energy-saving technology [2]

Based on the second-generation of energy-saving control system, the third-generation technology uses to transform the whole central air-conditioning by air-conditioning refrigerant replacement, fan-coil cleaning, add anti-wear agent, etc. When the variable frequency control system is selected to optimize the system, the whole central air-conditioning can reached 25 %-50 % energy saving. Now it is the newest energy-saving research direction.

## **2.2 The characteristic and problem of HVAC system**

Central air-conditioning which is a complex system composed by a large number of components, and the various components are often distributed throughout the entire



building. If the system wants to work out the capacity of adjust air to protect the indoor environment, the components must work together effectively. So the central air-conditioning system control is very important. [3]

The main features of central air-conditioning system are [3]:

- Multiple interferential

The function of air-conditioning system keeps the indoor environment suitable. Because of the impact of the solar radiation, the outdoor and indoor's air heat, and the heat dissipation of the indoor personnel, the air-conditioning system is multiple interferential.

- Control object diversity

There are many factors that affect the air-conditioning in the indoor environment. Also it will be used in various environment because the different status of architectural forms and uses of conditions.

- Control variable relativity

Generally, the control variable of air-conditioning system is the room temperature and humidity. The system often adjusts these two control variables at the same time. But these two parameters are restrained and influencing each other. Adjusting the temperature will change the saturation of partial pressure of the steam in the air. This will change the relative humidity in indoor; this is because when humidity is adjusted, the surface will be cooling and desiccant, or spray water and steam to cause humidification, so the air temperature will be changed.

- Object variability

The normal air-conditioning system has two kinds of operating conditions in summer and winter, and the requirement of the object and working principle are different in these two kinds of operating conditions. Because of these features, not only the air-conditioning control system often seems complex, but also the air-conditioning control system is diversified. So the air-conditioning control system develops and progresses by continuous research and engineering practice.

The main problems of central air-conditioning system are [3]:

- The system efficiency is not high because of the design margin of central air-conditioning system overload.
- Because the layout of the system is not reasonable, it increases the resistance of the system and energy consumption.
- There are poor control of operation and lack of effective energy management.

### **2.3 The energy saving measures of HVAC**

The measures of air-conditioning energy-saving system can be divided into three areas:

- The energy-saving by architectural design. It is an energy-saving idea which is a way of reducing energy sources.
- The energy-saving measures, which regulate the quality of the air-conditioning by reducing the cooling load demand.

- Energy-saving measure of central air-conditioning. The energy-saving idea is to improve the efficiency of the whole system by improving the design of central air conditioning and the coordination of controlling the devices.

### **2.3.1 The energy-saving by architecture design**

The building air-conditioning load is mainly affected by the impact of construction conditions. Thus to achieve energy-saving of air-conditioning system, firstly the building should be made energy efficient and air conditioning load. In the energy-saving of architecture design, there are several main aspects which are presented in the following:

- The heat transfer coefficient of exterior protected construction should meet the requirements of the relevant standards. Then it can be used to improve heat-insulating property of the structure of building and be used to use of thermal insulation materials.
- An air-conditioned building should avoid east-west position as much as possible. Also the surface area should be reduced and the light-colored surface should be used.
- The air-conditioned room, where temperature and humidity are required similar, should focus on the layout. An air-conditioned room should be avoided at the top of building. When it has to be located at the top, the roof should have good thermal insulation measures.
- The anti-infiltration facility is needed when the outer door is opened frequently.

### **2.3.2 Measures to decrease air standards**

The energy consumption of a system is higher if the indoor temperature and relative humidity is lower in summer or the indoor temperature and relative humidity is higher in

winter. Accounting to the data, if the indoor temperature is changed from 24 °C to 28 °C in summer, the cooling load can be reduced 36 %. If the indoor temperature is changed from 22 °C to 18 °C in winter, the heat load can be reduced about 55 %. Thus, in order to save energy consumption, the indoor temperature and humidity, which can meet requirements of production and human health and comfort, should be as high as possible in summer and as low as possible in winter.

### **2.3.3 Energy saving measures of HVAC system**

1. The selection of equipment should be appropriate and energy efficient products should be used. The flow of pump and the volume and air pressure of fan should be compatible with the requirement of system.
2. It is needed to improve the system's construction quality and minimize the water and air leakage in the piping system. Also it is needed to strengthen the insulation and reduce the loss of cooling capacity in the transmission.
3. The reasonable control and the use of the outdoor fresh air in a right way are some of the most effective energy-saving measures. In the case of the air-conditioned room which needs cooling in summer and heating in winter, if the outdoor fresh air volume is higher, the energy consumption is higher. In this case, the outdoor fresh air should be controlled to reach the minimum requirement for health. In winter, when indoors it is needed to provide cold wind, it should make full use of outdoor cooling air. By using all outdoor air, it can delay time of using the artificial cold source and save cold source energy consumption.
4. Consumption of conveying system should be reduced. Increasing pipe size and minimizing elbow valve can reduce the resistance of the air and water in the process of conveying, and then increasing the temperature difference of air and temperature

difference of water supply and backwater can reduce the flow of water. Both of them can greatly reduce energy consumption of conveying system.

5. One more measure is to use heat recovery technology. Air heat recovery equipment has two types which are sensible heat recovery equipment and total heat recovery equipment, and it is mainly used for recycling the consumption of discharge air in air conditioning system and directly passed to the fresh air. Heat recovery equipment can be individually set in the air discharging system of air conditioning, which can also be a function of modular air conditioning unit. It usually can save air load about 70 %.

It is needed to make sure that the automatic operation and management of air conditioning system. Ensure not only the air-conditioned room's temperature, humidity accuracy and savings in manpower, but also are an important part to preventing the loss of air conditioning system loss and saving energy. There are several main aspects:

1. Control of the indoor temperature and humidity: regulating the heat of air conditioning system, changing the cold (hot) water of fan coil and changing the fan speed to control room temperature. Similarly, changing the cooling water of coil, adjusting links for backwater valve and changing the mixing ratio of fresh return air can control the indoor relative humidity. If the room temperature or indoor relative humidity are not be controlled, it will appear too cold and dry in summer and too hot and wet in winter, and result in excessive consumption of energy.
2. Control of the best start and stop time: for intermittent operation of the air conditioning system, when the air conditioning stops running, the indoor air temperature changes and exterior protected construction retains a certain amount of heat storage capacity or cold. Before the room is used again, it is needed to adjust indoor temperature in a given value, and then there must advance give into the room more than the design condition for the load of cold (hot) of the cold (thermal) capacity allows. According to the temperature changing rule after the air conditioning stops running, it can obtain the

first downtime of refrigerating machine to maintain the room temperature in the minimum requirement.

3. Control air conditioning system running by microprocessor: a microprocessor is used to automatically control the operation of air conditioning system. Mainly by the microprocessor through the forecast the indoor and outdoor air state parameters, this is in order to minimize energy consumption as the basic evaluation function by maintaining comfortable indoor environment as constraint conditions. And according to the size of air conditioning load to judge and determine the cooling (heating) capacity number, command of operating units number (such as cold (hot) source unit, water pumps and fans), working methods and operating cycle.

The first method is the “root cause” to consider central air conditioning energy conservation. Starting from the source to stop the cooling load waste of the central air conditioning and to reduce the cooling load in the room, it can greatly reduce the cooling load demand and have more obvious energy saving effect. But it needs to involve a very wide range and is difficult achieve currently in China.

The second method can reduce central air conditioning energy consumption to some extent, but it is only do in the work on the “surface” and can not solve the intrinsic problem of the central air conditioning.

The third method is to consider central air conditioning energy conservation based on the system. Through controlling the reasonable operation of the central air conditioning, it can better solve the problems of central air conditioning and is a very practical way.

## **2.4 The principle and application of frequency conversion adjustment**

This chapter introduces how the frequency converter operates. It also introduces where the frequency converter can be used and how it can be used.

### **2.4.1 The basic principle of frequency converter**

In the energy-saving renovation of central air conditioning system, conversion technology plays as an important role. Frequency converter has two forms which are the AC-AC and the AC-DC-AC. The AC-AC frequency converter can be directly converted AC into AC which voltage and frequency can be adjusted. It is also called as a direct converter. The AC-DC-AC frequency converter is first converting power frequency AC into DC, and then converting DC into AC which voltage and frequency can be adjusted. It is also known as indirect frequency converter. [4]

### **2.4.2 Functions of variable frequency speed control**

#### 1. Frequency energy-saving function

The capacity of frozen pump motor is designed in accordance with maximum amount of heat exchange in the hottest day. Due to temperature changes in seasonal and diurnal, environmental and climatic differences and the movement of persons, in fact, heat exchange is much less than the design value. The amount of heat exchange is controlled by the freezing water flow, and the flow of freezing water is controlled by the motor speed of frozen pump. [5]

But electric power consumption of motor is controlled by its output power, output power  $P$  is proportional to the cube of the motor speed  $n$  ( $P \propto n^3$ ), and the motor speed  $n$  is proportional to the power supply frequency  $f$  ( $n \propto f$ ). So the motor speed decreased slightly,

that is slightly reduce power supply frequency and output power will be significantly decreased. If the motor speed can be adjusted by the heat exchange capacity of actual need, electrical power will be greatly reduced and thereby it is significantly saving energy. [5]

## 2. Soft start and stop function

When motor is started directly or Y/D start, the starting current is equal to 3-7 times of the rated current. It will cause serious impact to supply power system and electrical equipment, also the requirement of power system capability is too high. Start-current and vibration is extremely unfavorable to the life of the equipment, and when starting and stopping, the water hammer effect can easily cause pipeline rupture. But by using frequency control technology, it can be achieved the current started from scratch and the maximum current is no more than the rated current. This is the real soft start which not only can reduce the impact and demand of power supply capacity, but also can extend equipment life and reduced equipment maintenance costs.

## 3. The theoretical basis of frequency control can be energy saving

According to the basic characteristics of the pump and motor, there is always the following relationship:

Water flow and pump motor are in direct proportion,  $Q \propto P$ ;

Motor shaft power and the cube of pump motor speed are in direct proportion,  $P \propto n^3$ ;

Pump motor speed and frequency are in direct proportion,  $n \propto f$ ;

Pump head and the square of water flow rate are in direct proportion,  $h \propto Q^2$ ;

Pipeline resistance is proportional to the cube of velocity,  $Z \propto v^3$ ;

Therefore, it can change the frequency to reduce the pump motor power to suit the changes in water flow. [6]



#### 4. The components of variable frequency energy-saving system of central air conditioning

The variable frequency energy-saving system of central air conditioning needs a combination of hardware and software technology. It means using of vector control integrated with the use of the techniques which include dynamic process corresponding compensation, constant torque regulator and transient suppression. The new products of frequency conversion technology, which through the synchronous tracking, pressure regulating, phase modulation, adjust the frequency and transient suppression in one, have following features: [7]

- Control voltage and limit current which under the conditions of constant torque adjustment can make the motor load in the voltage and current of operating status which have the most appropriate, the smallest and most economical power.
- The optimization frequency modulation technique, which is controlled by vector control and fuzzy logic, has all the most advanced features of general converter.
- Achieve dynamic power factor compensation by the computer track of sample.
- Transient flow interference suppression technique filtrates transient flow fluctuations and reduces the loss and interference.

It is because of these advantages, the central air conditioning frequency energy-saving has the theoretical basis and the feasibility of implement control.

## 5. The application of frequency technique in the central air conditioning system

- Ending the air supply of the inverter control of central air conditioning

In the central air conditioning system, the transmission medium is usually cold or warm water. The clean air will be fully in contact with the heat exchanger in the air terminal and the clean air flows directly into the interior by fan to achieve the purpose of regulating room temperature. When the transport medium (water) temperature is constant, the cold (heat) of indoor will be changed by changing the air flow, and then the indoor temperature can be more easily adjusted. This can be set room temperature according to requirements which are needed. The air flow is controlled by adjusting the fan speed. By using the converter, fans achieve continuously variable, while in the frequency, the voltage input is changed also, thus it can save energy, reduce system noise and improve comfortable and economical use central air conditioning. [8]

The advantages of VAV control are: saving energy significantly with reducing the air conditioning unit noise, reducing the amount of labor intensity, reducing the impact on power with soft-start and steady speed of converter. The disadvantage is large investment costs. [9]

- Circulating Pump Frequency Control of central air conditioning [10]

In the freezing water system, the output water temperature depends on the setting of evaporator and return water temperature depends on the heat load of building. Between output water temperature and return water temperature, the central air conditioning freezing water's maximum design temperature difference is 5°C. As shown in Figure 2-1, the closed-loop control system is used which includes temperature transmitter, PID temperature regulator and the transducer on the evaporator outlet pipe and return pipe. Through the freezing water temperature's difference (e.g.  $\Delta T = 5^\circ\text{C}$ ) the freezing water pump speed is controlled which can make the corresponding changes in heat load changes.

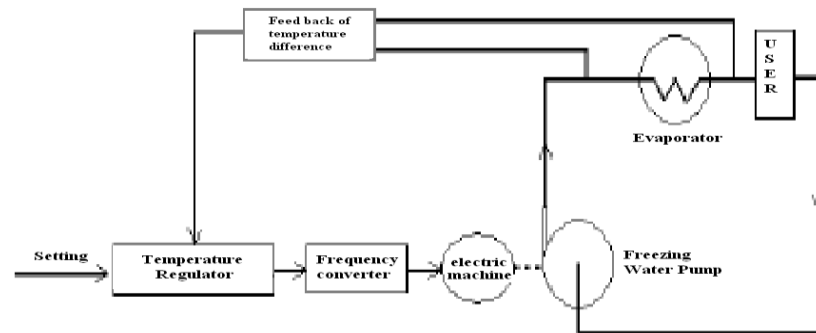


Figure 2-1. Controlling project of the freezing water pump [10]

In cooling water system, as low-temperature cooling water's temperature (going into the condenser) depends on ambient temperature and cooling tower's operating condition, it is only controlling the high-temperature cooling water (going out of the condenser) to affect the temperature difference. With a closed-loop control system which includes temperature transmitter, PID temperature regulator and the transducer, high-temperature cooling water's temperature is controlled in  $T_2$  (e.g. 37°C), so that the speed of the cooling water pump corresponding to the heat load changes. [10]

#### 6. The effect after the improvement by frequency converter of the circulating pump [11]

- On the air-conditioning systems, to ensure temperature and pressure of turnover water of water chilling unit in the best range of work, the flow can be adjusted automatically according to load needs and the elimination of throttling losses, the instantaneous flow interference and harmful overload of system, it not only effective in energy conservation, but also effectively control the main high-pressure low-flow conditions which can substantial increase in the mainframe and air conditioning system efficiency, can greatly reduced the number of equipment failures and can improve working conditions throughout the air conditioning system.
- To soft start the motor (the maximum inrush current is less than the rated current) and device, and to achieve the protection features of the over-voltage, over-current and

phase loss, which can eliminate the impulse of current and electric arc, significantly reduce equipment loss and reduce the temperature and noise, to protect the power system. And also it can extend equipment life, reduce the number of accidents that may occur and reduce maintenance costs.

In the central air conditioning water system, variable frequency control for coolant pump and refrigerant pump can play a significant energy saving role. Frequency conversion control technology in secondary coolant water pump and high-rise building high-zone air conditioning water system has been promoted, and it is also feasible in one refrigerant pump system and coolant pump system. It needs elaborative design for the specific conditions of the project which can achieve the desired energy saving and ensure safe operation of the air-conditioning system and equipment. [11]

Inverter technology has the following advantages in air conditioning system [12]:

- It saves the maximum pump energy consumption.
- Frequency converter has voltage regulation function which can provide soft-start for pump motor and little effect on the grid. Inverter's infinite speed variation, motor's smooth start and no impact of noise can improve its service life.
- Winter and summer can be combined with a circulating pump system when selecting is reasonable. Water system has seasonal adjustment by frequency converter and there are no questions of lowering the pump efficiency.
- When more pumps are running in parallel, it can reduce the number of pumps. At the same time realize the automatic control of refrigerating machine, water pump running, start and stop by the process control and easy to management.

### 3 Development and Testing of HVAC Control System

In this chapter, the development of energy-saving control system of central air conditioning is presented for refrigerating machine, cryogenic pump, coolant pump, cooling tower fan and the related equipment which are in the equipment room of refrigeration station.

#### 3.1 Structural design of control system

The equipment is needed more to control and manage in equipment room of refrigeration station. These devices are related. In order to develop more clearly and efficiently the energy-saving control system, this part firstly makes a structural design of the system which has three levels: center energy management layer, field services management layer and detection and control layer. Between the layers, the bus is connected to realize the whole system network integration, as shown in Figure 3-1.

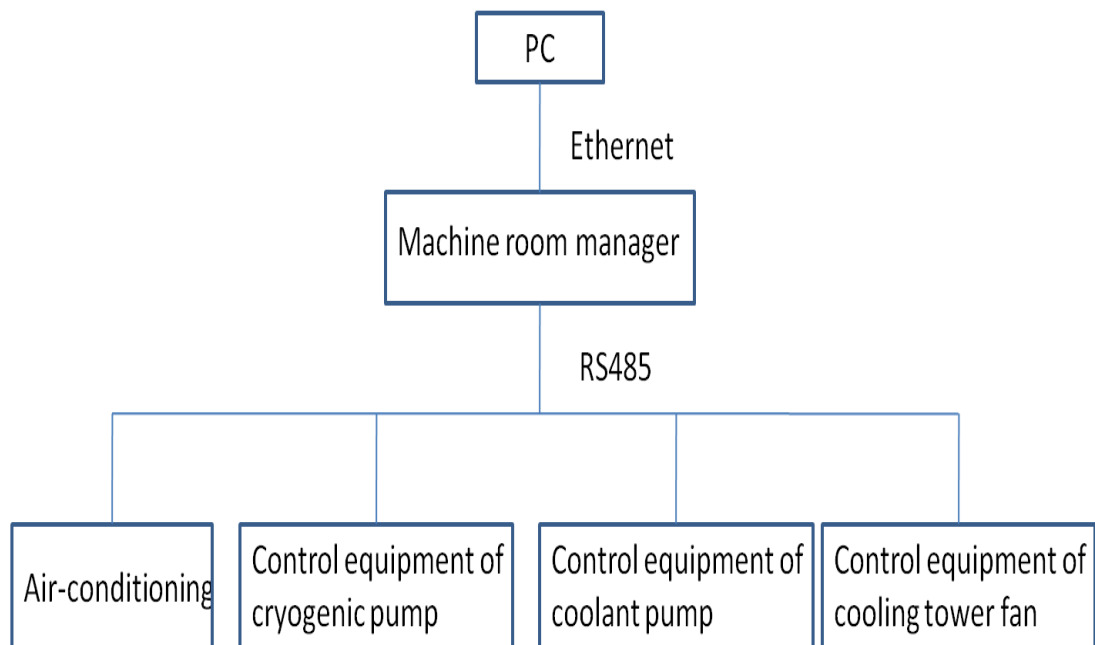


Figure 3-1. The composition program of central air conditioning energy saving control system

The introductions of the functions of the three layers are introduced here:

- Center energy management layer

It is composed by PC and supervisory computer software. Its function is to bring together the collection conditions that are the energy-saving of central air conditioning system and the data of equipment running, and it analyses the performance data and real-time display and saves data into a database to complete remote control.

- Field service management layer

It is composed by a room server and related application programs. Its function is, firstly, through BACnet communication protocol to collect test data and device operating conditions. Secondly, through TCP/IP protocol, the data of cooling station is sent to center energy management layer and the remote control commands of center energy management layer are received. Lastly, it analyses the information of data fusion processing and overall energy efficiency to control the operation of equipment in cooling station which is to achieve the best overall energy-saving.

- Detection and control layer

As the bottom of the controller, its main function is the completion of data acquisition and to control device object. At the same time through the BACnet protocol it sends collection data and operational status of equipment to the Field Service Manager and receive control commands. In the detection and control layer, a node controller is developed according to the different types of control devices to design the chiller subsystem, cooling pump subsystem, cryogenic pump subsystem and cooling tower subsystem. Each subsystem not only independently controls the local energy conservation, but also is a subject to the overall energy service control manager.

This development node controller, as shown in Figure 3-2, is responsible for the equipment which includes: two refrigerating machines, three chilled water pumps, three cooling water pumps, three cooling tower fans, valves, etc.

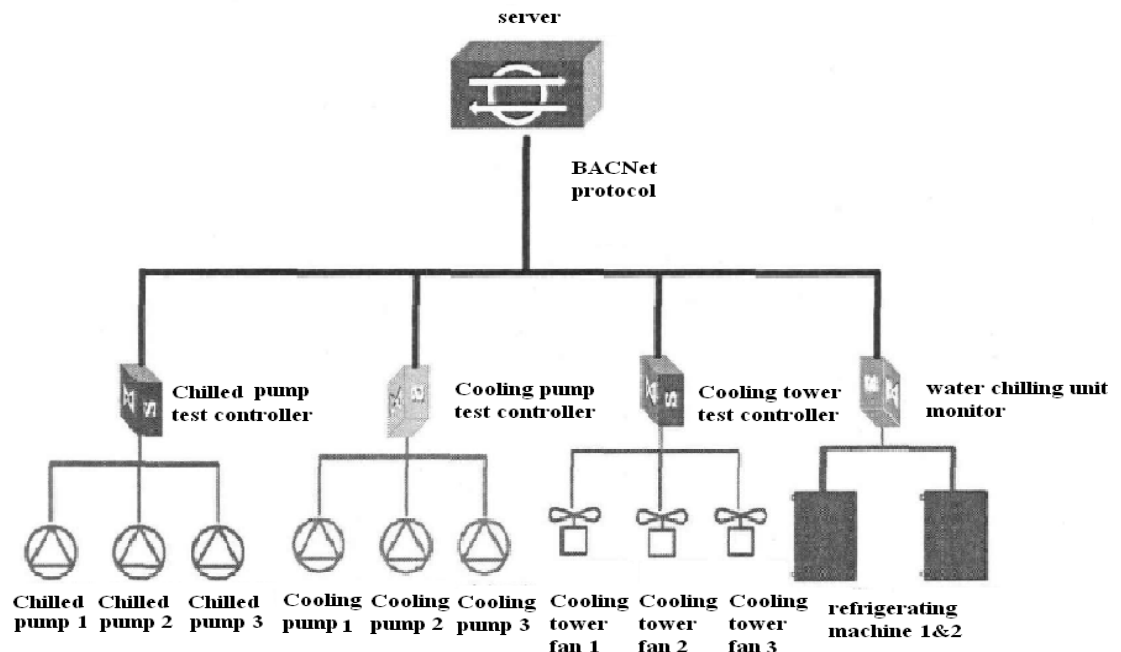


Figure 3-2. Frozen station room controller object graph

### 3.2 The function of control system

#### 1. Server function of equipment room

Equipment room server is equivalent to a small-scale LAN controller which is specialized management refrigeration station node controller to coordinate action between the node controllers. It can complete the overall system energy saving control algorithm and its specific functions are as follows:

- Manual/automatic detection
- Frozen station equipment startup, shutdown process control

- The overall optimal control algorithm
- Indoor and outdoor temperature measurement
- RS485 communication
- Ethernet communication
- Communication and fault alarm

## 2. Refrigerating machine controller function

Refrigerating machine is the most important component of central air conditioning system and it is known as the heart of the central air conditioning system. Controller is responsible refrigerating machine's startup/shutdown and monitor of the chiller operating conditions to meet other equipment running in refrigeration station. It includes:

- Manual/automatic detection
- Indoor temperature/outdoor temperature detection
- Cold temperature protection
- Refrigerating machine on/off control
- Chiller fault detection and alarm
- RS485 communication
- Communication fault detection and alarm

## 3. Cryogenic pump controller functionality

The controller main task is to complete the frequency conversion control of the chilled water pump to achieve energy conservation and to monitor frozen water related equipment. At the same time for the central air-conditioning and room manager discrepancy, the controller increases the valve state detection and remote alarm capabilities. Its functions are as follows:



- Manual control operation: using hand-operating mode, variable-frequency drive control the pump start, stop and run
- Automatic control operation: using automatic control, equipment room server control all the equipment's start, stop and run
- Variable-frequency drive output control
- Variable-frequency drive detection and alarm
- Frozen valve control, fault detection and alarm
- Chiller condition monitoring
- Chilled water flow rate detection
- Chilled water pump fault detection and alarm
- RS485 communication
- Communication fault detection and alarm

The controller's highest priority is manual control, then the equipment room server and remote PC control. When the communication is normal, the controller follows the energy saving control mode which can make whole equipment room server optimization. When the communication fails, the controller uses the best cryogenic pump energy-saving mode to independent control.

#### 4. Cooling pump controller functionality

The controller's main task is to complete the frequency control of cooling pump and monitoring of cooling water related equipment, which includes the cooling water entering and leaving temperature, water valves' closure, cooling pump frequency control, pump start and stop detection and control and signal communication.

Its main functions are as follows:

- Manual control operation: using hand-operating mode, variable-frequency drive control the pump start, stop and run

- Automatic control operation: using automatic control, equipment room server control all the equipment's start, stop and run
- Variable-frequency drive output control
- Variable-frequency drive detection and alarm
- Frozen valve control, fault detection and alarm
- Chiller condition monitoring
- Chilled water flow rate detection
- Chilled water pump fault detection and alarm
- RS485 communication
- Communication fault detection and alarm

#### 5. Cooling tower controller functions

The main task of the cooling tower controller is the operation of cooling tower blower control to meet the cooling water temperature of refrigerating machine requirement. When the condition is meet the requirement, controller can achieve energy-saving of cooling towers and fault detection function of cooling tower equipment.

The functions are as follows:

- Blower switch control
- Cooling water temperature detection
- Cooling tower temperature detection
- Valve control
- Flow switch detection
- Blower fault detection and alarm
- Blower running time and the number of records
- RS485 communication and fault detection and alarm

Cooling tower controller not only receives the server's control commands to achieve the control of the blower (to achieve and overall energy efficiency), but also has an own control algorithms in order to interrupt the communication system can run as usual.

### **3.3 Software design**

Software is the soul of the computer. A computer has a good software system which the computer's performance will be the best. In the central air-conditioning control system design, there are many different tasks and each task is different for real-time requirement of CPU. In order to let the task meet the entire real-time requirement and to facilitate future software upgrades and maintenance, the system uses embedded operating system to achieve the development of central air-conditioning control system. There are some specific descriptions following. [13]

#### **3.3.1 Embedded real-time operating system**

Embedded system is the computer system which is for the purpose of embedded application. It will combine computer hardware and software to form a dedicated computing device to achieve the completion of specific functions and tasks. The embedded system advantage has small software code, highly automated and fast response and it can easily suit for the real-time requirement and multi-task system. [14]

RTOS (Real-Time Operating System) is an operating system which can support the work of real-time control system. It is a program set which makes the hardware of computer system available by the software or firmware achieved and is a software layer between the programmer and the machine hardware. [14]

RTOS is a new design idea and an open software framework. It has the basic function of the operating system and can control the operation on the real-time system. According the priority of each task, it also can make a reasonable allocation of CPU and occupied time of resource among them. As the RTOS can make application system to be divided into multiple tasks which greatly simplify the design of application system, software designers can not significantly change the other tasks in the system to increase or delete a task and greatly reduce the development time and the software development mission. It meets the complicated micro-controller application requirement. [14]

### 3.3.2 Control flow's design based on RTOS

1. Service Controller controls the whole system power on and shutdown

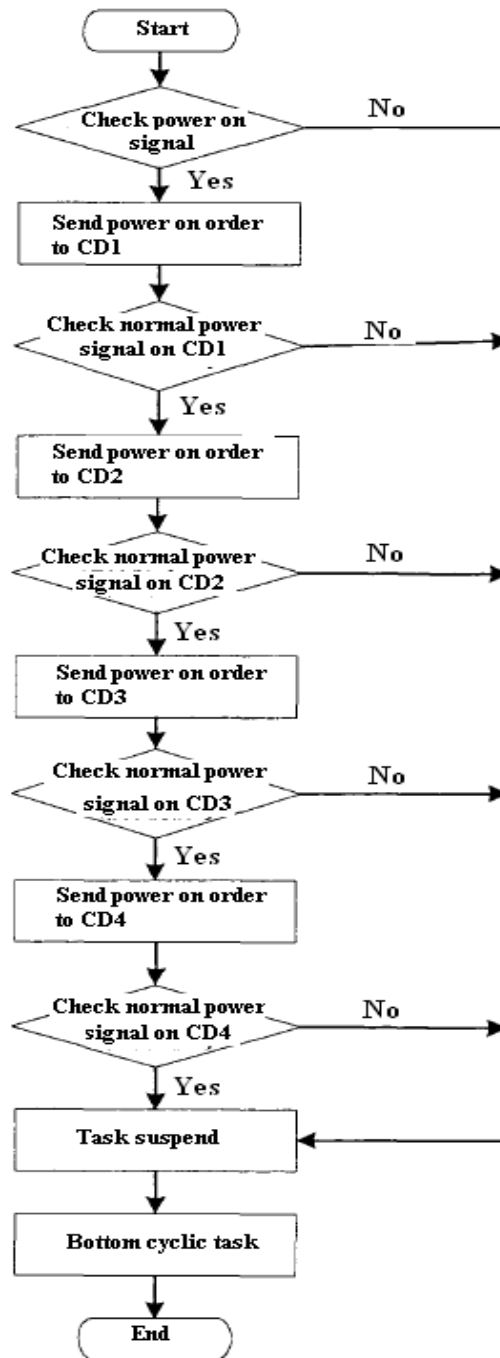
Power on Process: Opening the cooling pump → Opening cooling tower fan → Opening a chilled pump → (20 minutes delay) → Opening the refrigerating machine.

Flowchart is shown in Figure 3-3.

Shutdown process: closing refrigerating machine → (20 minutes delay) → closing chilled pump → closing cooling pump → closing cooling tower fan. Flowchart is in *Appendix 1*.

2. Other equipment control flow

Control flow of chiller, the chilled pump interrupt processing flow and cooling tower control flow are shown in *Appendices 2 to 4*.



Symbol Description:

SD = frozen-stop service manager

CD1 = cooling pump controller

CD2 = cooling tower controller

CD3 = freezing pump controller

CD4 = water chiller controller

Figure 3-3. SD Power on Process

### **3.4 Hardware design**

Hardware design includes node controller's design and equipment room server's design which can more effectively control the system.

#### **3.4.1 Node controller**

The node controller of system develops by using PIC24FJ64GA006 microcontroller of Microchip Inc. Microcontroller features are described as follows: [15]

- Low-power and high-performance 16-bit SCM
- Internal 128K on-chip Flash
- Software stack can facilitate the achievement of the development of embedded operating system
- RICC on-ship
- On-chip is also with compatibility of 10-bit analog-digital conversion module (A/D)
- Two USART communication circuits and five PWM output circuits.
- With five 16-bit internal timer / counter

Node controller includes chilled pump controller, cooling pump controller, cooling tower controller, and water chiller controller. Although these controllers' object and completion of the function are not the same, they are basically the same basic circuit and almost all need the following functions: data sampling, filtering, PWM output, RICC real-time timer, digital input / output, RS485 communication, EEPROM and so on.

Node controller features are presented in the following figure:

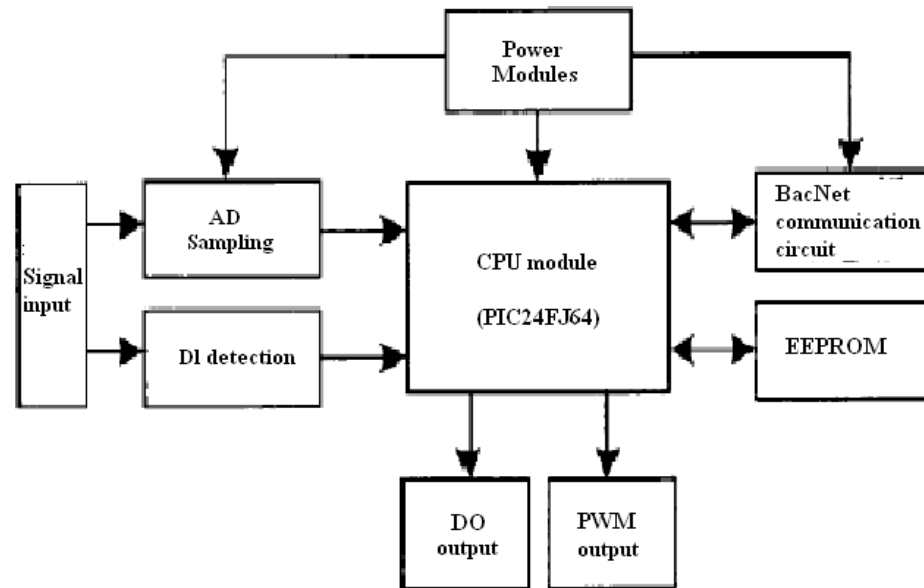


Figure 3-4. Node controller function structure chart

In the basic circuit of node controller, there are AD sampling circuits, PWM control circuits, RS485 communication circuits, power circuit, DO drive circuit and DI detection circuit. There are brief introductions of these below.

### 1. PWM control circuit

CPU output signal is the 100 KHz PWM signal. First it goes through the DC signal which is smoothly commutated by low-pass filter. Then, after the first operational amplifier is used to amplify the output signal range between 0 to 10V, and the last operational amplifier is used to ensure the equipment of the output capacity. [16] (Figure in *Appendix 5*)

### 2. Minimum CPU circuit in node controller (*Appendix 6*)

### 3. Signal filtering circuit

Because it is susceptible to noise interference in the AD sampling circuit, the filter circuit

and low-pass filter circuit should be used for processing in the circuit. [17] (Figure in Appendix 7)

#### 4. The power processing circuit

When a device requires a protection circuit which has a big overall flow and can achieve accurate protection, the protection circuit often requires good coordination between several protection devices to achieve the ideal protective effect. When the Voltage Dependent Resistor (VDR) is in parallel with Transient Voltage Suppressor (TVS) directly, even if the flow of VDR meets the total surge protection requirement of equipment, TVS will be damaged first and can not exert the advantage of VDR. So we have a 7 mH inductor in series with VDR and TVS. [18]

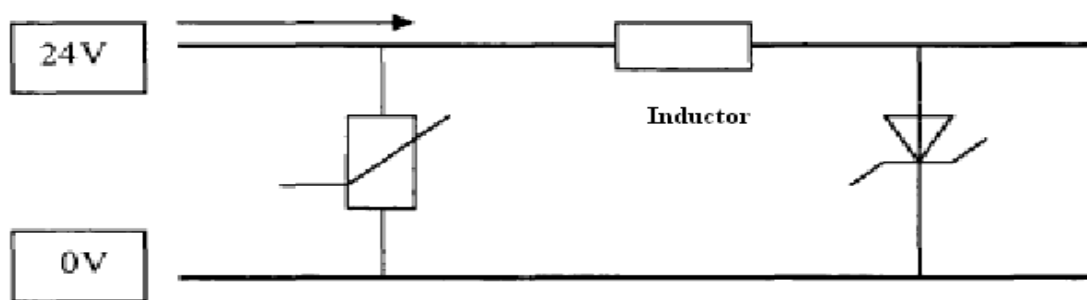


Figure 3-5. The schematic diagram of cooperate between VDR and inductor

#### 5. BACnet communication circuit

BACnet MS/TP uses RS-485 (also called EIA-485) standard as a physical layer and uses a balanced data transmission mode. The transmission medium of RS-485 uses cheaper shielded twisted pair and there can be articulated multiple receivers on transmission medium. It has a strong anti-jamming capability, a easy network connection and a long transmission distance. The transceiver of RS-485 is using SN65LBC184 of TI Company as communications chip and it is the pin-compatible with the SN75176. [19]



As the controller in the field distribution is generally in the 50 m-100 m away, these appear some static electricity and interference signals data communication line such as surge voltage. For protecting the CPU and RS-485 chip, two TVS are used in the interface and optical coupling device is added between CPU pins and RS-485 chip to isolation. [19] (Figure in *Appendix 8*)

#### 6. DO drive circuit

In order to protect the SCM IO pin, optical couplers are used for power isolation and increasing the transistor as an intermediate driver. Then through a 24V relay as a dry contact output, it can control device with any type of power. For preventing too large electromagnetic interference on the relay coil and contacts, there is increasing fly-wheel diode (FWD) in the both ends of the coil and paralleling a 1000pF/2KV capacitor in the both ends of contact. (Figure in *Appendix 9*)

#### 7. DI detection circuit

DI detection circuit can protect the input pins of SCM and transform the input voltage into 3.3V which is the requirement of CPU by optical coupling device. (Figure in *Appendix 10*)

### **3.4.2 The design of equipment room server**

The controller of equipment room server requires the circuits which have Ethernet communication, RS-485 communication, the temperature acquisition circuit, digital signal detection circuit, digital signal output control circuit, storage circuit and real-time clock circuit, as shown in Figure 3-6. RS-485 communication, digital signal detection circuit, digital signal output control circuit, storage circuit and real-time clock circuit are similar in node controller, so the description is not repeated again here.

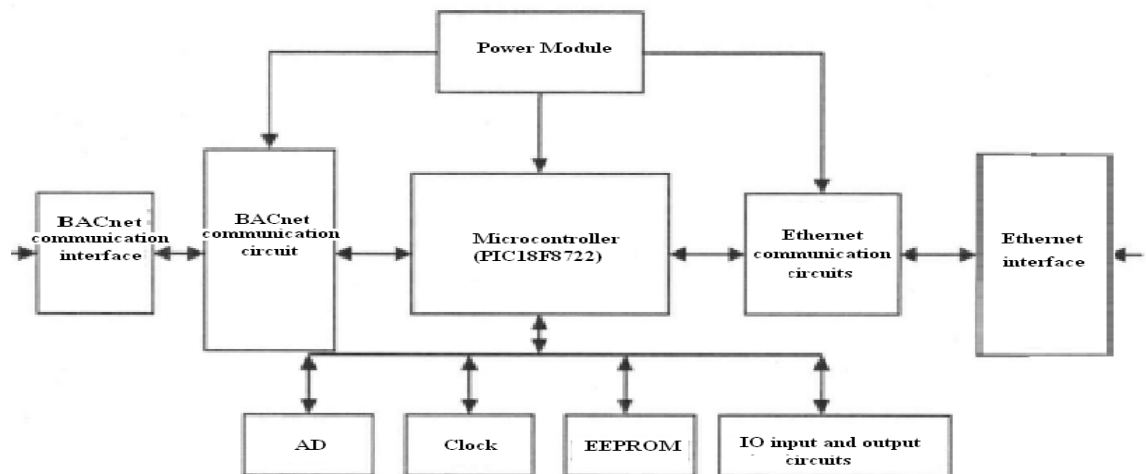


Figure 3-6. Schematic diagram of the equipment room server hardware

### 1. Micro-controller

When equipment server is implementing data communication, data analysis, data storage, control algorithms and other functions, the system has relatively large spending. So it requires of CPU to have more abundant resource, enough storage space and computing ability. The system uses Microchip Company's PIC18F8722 micro-controller to achieve the design of the equipment room server. The performances of PIC18F8722 are as follows [20]: (Figure in *Appendix 11*)

- Powerful processing capability. PIC18 series is 8-bit microcontroller and uses Reduced Instruction Set Computing (RISC) architecture. It also includes an 8 x 8 multiplying unit. It requires only one single instruction cycle to implement multiplication by hardware. The PIC18 device has higher calculation throughput and it reduces the code size for multiplication algorithms. So it can be used in many applications where as the previous can only be used in digital signal processors.
- Fast computing speed. PIC18 device uses Harvard architecture which separate instruction bus and data bus and two-stage pipeline instruction fetch and execution. So it has a larger advantage compared with other 8-bit micro-controller on the code compression and implementation speed.

- Variety power mode. It provides seven working modes and can be more effective for power management.
- 128K Flash, 4K RAM, 1024 Bytes EEPROM in chip

## 2. Ethernet communication circuit

In the system of Ethernet communication design, Ethernet controller is selected as the chip that is RTL8019AS. The chip's main characteristics are as follows [21]: (Figure in *Appendix 12*)

- Compatible with Ethernet and IEEE802.3 protocol. Transmission wire cables are 10Base2, 10Base5, 10BaseT.
- Support for 8-bit and 16-bit data bus
- Support for full-duplex Ethernet function to speed up the channel bandwidth
- Built-in 16KB SRAM. It can be used for RX/TX buffer and to reduce the speed requirements of the main processor.

## 3. Data filter circuit

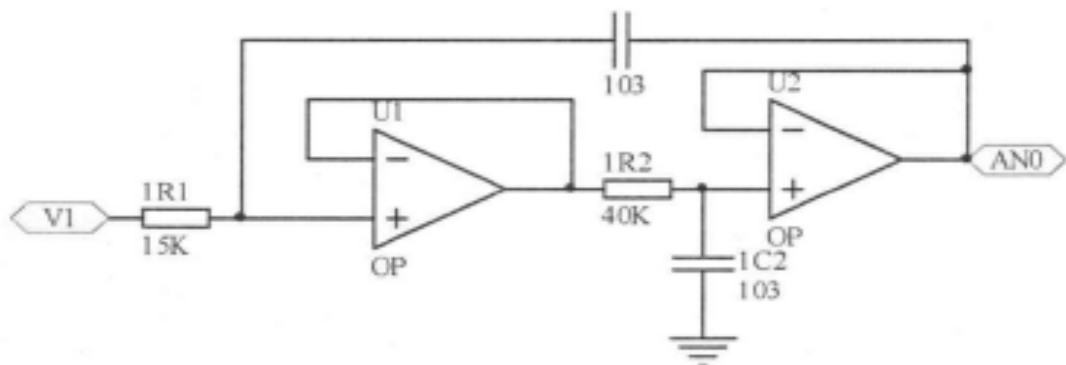


Figure 3-7. Simulation signal filter circuit

The advantage of the second-order low-pass filter (shown in Figure 3-7) is that the two operational amplifiers of this filter circuit are used as a voltage follower. So the sensitivity requirement of operational amplifier opening loop gain is not high for the circuit.

## **4 Research on energy saving of central air conditioning system in Nanchang HongKeLong Supermarket (HKLS)**

In this chapter, there is a project design of central air conditioning system for HKLS is discussed. The chapter will introduce the basic parameter, preliminary design and the equipment selection.

### **4.1 Calculation condition**

The calculation condition, which includes the basic meteorological parameters, the design of requirement and the indoor condition, is extrinsic factor of environment which may be affected by the central air conditioning work efficiency.

#### **4.1.1 Calculation of meteorological parameters**

Summer ventilation temperature (dry bulb): 32°C

Summer outdoor atmospheric pressure: 969kPa

Winter ventilation temperature (dry bulb): 6°C

Winter outdoor atmospheric pressure: 987.2kPa

Summer air-conditioning temperature (dry bulb): 35.5°C

Summer air-conditioning temperature (wet bulb): 27.0°C

#### **4.1.2 The scope and requirement of the design**

The scopes of the design are:

- The design of ventilation and exhausting system for fire protection in underground car park

- The design of summer air-conditioning and exhausting system for supermarket on the 1<sup>st</sup> and 2<sup>nd</sup> floor
- The design of positive pressure air supply in smoke prevention staircase
- The design of ventilation and exhaust system in underground equipment room

Design requirements and conditions are listed in Table 4-1 and Table 4-2

Table 4-1. Fire protection for the building

NO.	Area	Design Content			
		Heating	Ventilation	Air conditioning	Exhausting system
1	Basement		★		★
2	1st floor		★	★	★
3	2nd floor		★	★	★
4	Smoke prevention staircase		★		★

Table 4-2. Design indoor condition of air conditioning

NO.	Area	Temperature		Humidity		Noise level(dB)	Fresh air targets (m <sup>3</sup> /h)
		Winter	Summer	Winter	Summer		
1	Basement	/	24-26°C	50%	70%	55	15/person
2	1st floor	/	24-26°C	50%	70%	55	13/person
3	2nd floor	/	24-26°C	50%	70%	55	13/person

## 4.2 Preliminary design

Engineering design is central for air conditioning. It only requires designing the smoke control and ventilation in basement. It also requires designing summer air-conditioning, smoke control and ventilation on 1<sup>st</sup> and 2<sup>nd</sup> floor of the supermarket.

### 4.2.1 Purification of air conditioning system design

The ground floor supermarket:

- The central air conditioning system should be used in the central area.
- For the shop next to the pedestrian street, it can be used semi-centralized air conditioning system (fan coil and DOAS) which can self-regulate according to the indoor load condition because the requirements of the indoor air quality, temperature and humidity are different
- For the area that is close to the door and a contact with the outside, it can be directly used independent air-conditioning unit which have fan coil, as shown in Figure 4-1 to Figure. 4-4 due to the infiltration of outdoor fresh air and do not need add fresh wind,



Figure 4-1. Layout of fresh air system  
in Area 1

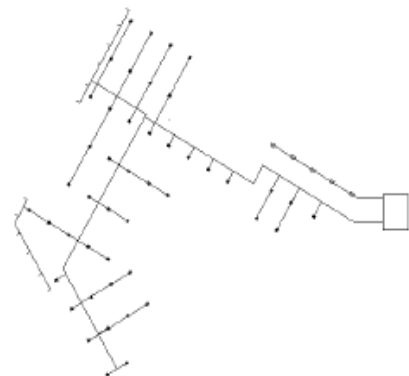


Figure 4-2. Layout of CACS in Area 2

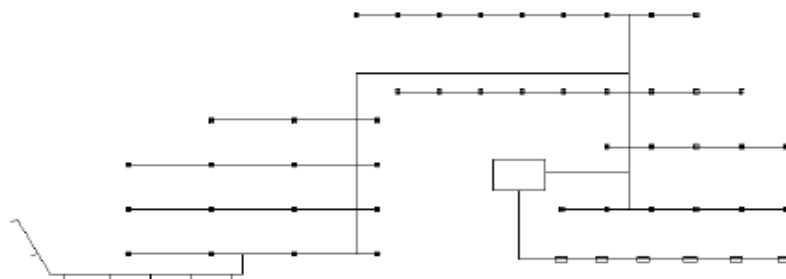


Figure 4-3. Layout of CACS in Area 3

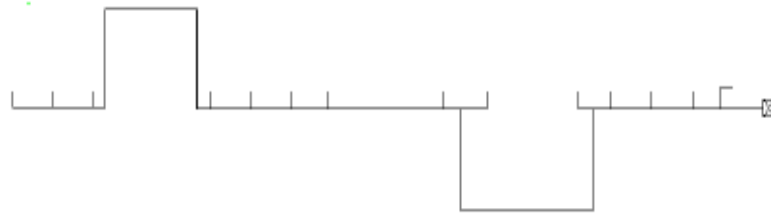


Figure 4-4. Layout of fresh air system in Area 4

The 2<sup>nd</sup> floor:

- A centralized air conditioning system should be used in the central area.
- The surrounding shops use semi-centralized (fan coil and DOAS) air conditioning systems.
- Few areas which are near the door and have fresh air infiltration are using independent air-conditioning system with a fan coil, as shown in Figure 4-5 to Figure 4-8.

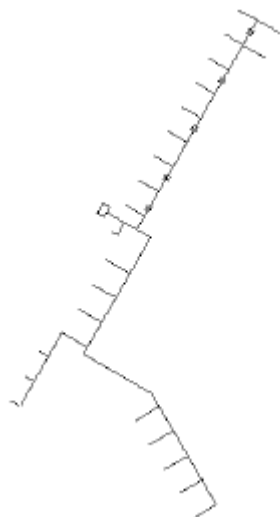


Figure 4-5. Layout of fresh air system  
in Area 1

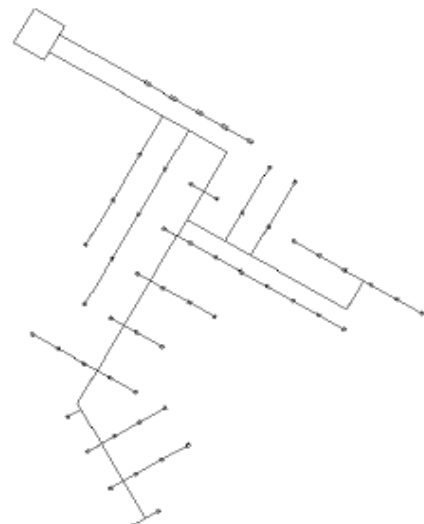


Figure 4-6. Layout of CACS in Area 2



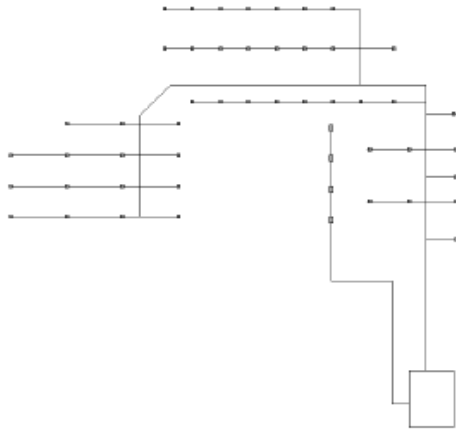
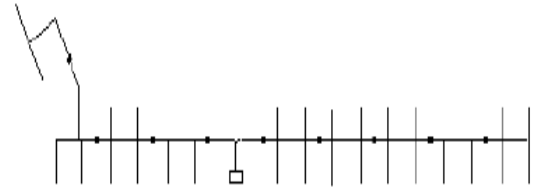


Figure 4-7. Layout of CACS in Area 3

Figure 4-8. Layout of fresh air system  
in Area 4

#### 4.2.2 Cold water system design

When it only requires cooling and does not require heating, the double-gate water system is used. When the cool storage is not needed to consider and the requirement of comfort of air conditioning are not high, the closed water system is used. The closed water system is rarely produces dirt and corrosion in a line, the little pump power consumption and it does not need to conquer the hydrostatic head of system. Due to the comfort requirement of air conditioning is not high and in order to reduce investments, both horizontal and vertical pipe systems use direct return systems.

#### 4.2.3 The control sequence of air conditioning system

Boot sequence in summer: Cooling tower fan → electric butterfly valve on the water supply pipe of cooling tower → cooling water pump → chilled water pump → chiller.

Shutdown sequence in summer: Chiller → cooling tower fan → cooling water pump → electric butterfly valve on the water supply pipe of cooling tower → chilled water pump.

#### 4.2.4 Noise elimination and shockproof method

The muffler should be added on the import and export pipeline of air conditioning and fan. It is necessary to do the shock absorption which is required to add a rubber vibration pad on the bottom of chiller, pump and other operating equipment. Also it is necessary to use hanger frame when hoist fresh air unit, fan coil and muffler are shockproof.

### 4.3 The equipment selection of air-conditioning and cold and heat source

#### 4.3.1 Air handling equipment selection

Central air conditioning and semi-central air conditioning are chosen by required cooling capacity which is calculated by the area ratio of target area for the layers and the total required cooling capacity of layers (because the parameter requirement in each area in each layer is the same). The fresh air unit is selected according to the capacity of fresh air.

The 1<sup>st</sup> supermarket's floor air handling equipment selection results are as shown in Table 4-3 to Table 4-5

Table 4-3. Two combined air conditioning units

Area	Air handler model number and specifications	Air quantity m <sup>3</sup> /h	Cooling Capacity kW	Excess pressure Pa	Power kW	Water flow m <sup>3</sup> /h	Number of calandria
2	YSM-25L-7080 HVCC	50810	443	500	22	70.88	8
3	YSM-25L-7070 HVCC	42090	385	500	22	53.6	8

Table 4-4. Two air-processors

Area	Air handler model number and specifications	Air quantity m <sup>3</sup> /h	Cooling Capacity kW	Heating Capacity kW	Excess pressure Pa	Power kW	Water flow m <sup>3</sup> /h	Number of calandria
1	YAH02	2000	33	31	100	0.32	5.4	6
4	YAH02	2000	33	31	100	0.32	5.4	6

Table 4-5. Hidden fan pipe

Air handler model number and specifications	Air quantity m <sup>3</sup> /h	Cooling Capacity kW	Heating Capacity kW	Excess pressure Pa	Power kW	Water flow m <sup>3</sup> /h	Number of calandria	Number of units
YGFC-03-CD-4-H-X-F	470	4.01	6.02	50	47	0.7	4	2
YGFC-06-CD-4-H-X-F	880	6.36	9.54	50	108	1.19	4	13
YGFC-08-CD-4-H-X-F	1380	7.33	9.09	50	150	1.74	4	24

The 2<sup>nd</sup> supermarket's floor air handling equipment selection results are as shown in Table 4-6 to Table 4-8.

Table 4-6. Two combined air conditioning units

Air handler model number and specifications	Air quantity m <sup>3</sup> /h	Cooling Capacity kW	Excess pressure Pa	Power kW	Water flow m <sup>3</sup> /h	Number of calandria
YSM-25L-6070 HVCC	36210	329	500	18.5	52.6	8
YSM-25L-6070 HVCC	36210	329	500	18.5	52.6	8

Table 4-7. Two air processors

Air handler model number and specifications	Air quantity m <sup>3</sup> /h	Cooling Capacity kW	Heating Capacity kW	Excess pressure Pa	Power kW	Water flow m <sup>3</sup> /h	Number of calandria
YAH05	5000	85	79	100	0.45×2	14.4	6
YAH05	5000	85	79	100	0.45×2	14.4	6

Table 4-8. Hidden fan pipe

Air handler model number and specifications	Air quantity m <sup>3</sup> /h	Cooling Capacity kW	Heating Capacity kW	Excess pressure Pa	Power kW	Water flow m <sup>3</sup> /h	Number of calandria	Number of units
YGFC-06-CD-4-H-X-F	880	6.36	9.54	50	108	1.19	4	24
YGFC-08-CD-4-H-X-F	1380	7.33	9.09	50	150	1.74	4	23
YGFC-10-CD-4-H-X-F	1540	8.26	11.15	50	185	1.98	4	10

### 4.3.2 Cold and heat source selection

In summer the design of cooling load is 5700 kW, it is also needed to consider the safety margin and then the total cooling load is  $5700 \times 1.1=6270$  kW. So Nanchang HKLS selected three centrifugal chillers. The cooling capacity of a single one is 2110 kW. The parameters are shown in Table 4-9.

Table 4-9. Parameters of the chiller units

Chiller model	Cooling Capacity kW	Power kW	Chilled water flow m <sup>3</sup> /h	Cooling water flow m <sup>3</sup> /h
YKEBEBH55CPE	2110	378	363	428

In the vapor compression refrigeration equipment, a centrifugal chiller has strong refrigeration capacity and lower energy consumption. It should be precedence in the large project which has big air conditioning load.

## 4.4 Automatic Control on Air-conditioning and Cooling/Heating source system

Automatic control can help fewer people to control the system. It will be used at fan system, water system and smoke exhaust system. All of them can help the central air conditioning system to reduce the labor force and the manual operation mistake

### 4.4.1 Automatic control of fan in air conditioning unit

The fan control system of air conditioning unit is shown in Figure 4-9. When the load of air-conditioned room changes, the room temperature sensor sends a signal and transmits it to the inverter. The inverter generates corresponding frequency and acts on fan which changes its speed to change the amount of wind.

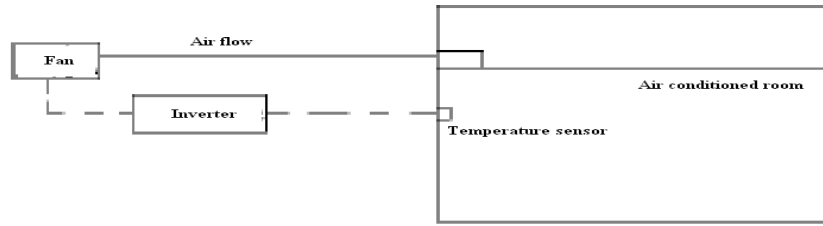


Figure 4-9. The control process of air condition unit fan

#### 4.4.2 Automatic control of water system

Automatic control of water system is achieved through the control of electric regulable three-way valve of by-pass pipe which is between water collector and water segregator. Because the load changes in air-conditioned room, the inverter controls the speed change of air conditioning unit. But the amount of chilled water which flows through air conditioning unit is unchanged, so that the temperature difference of supply and return chilled water changed is.

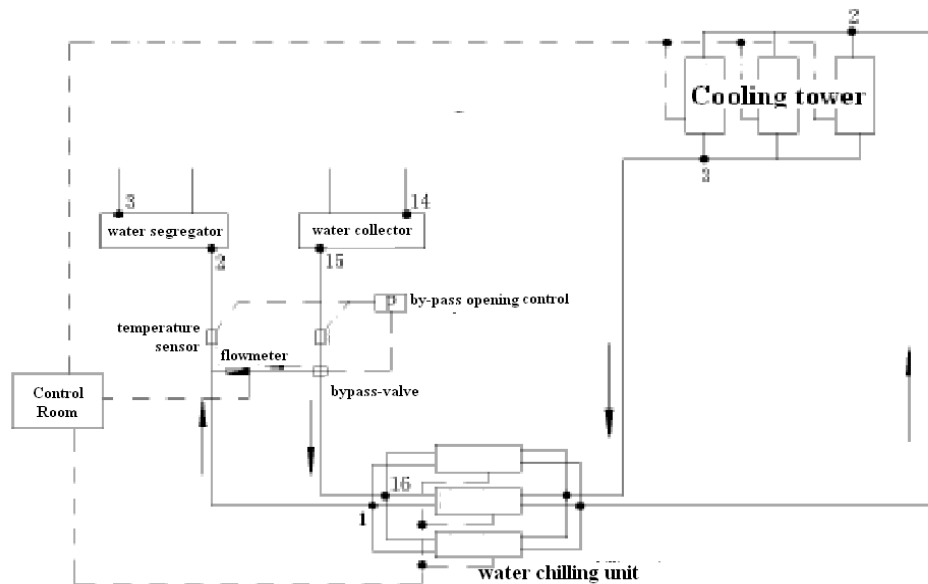


Fig 4-10 Automatic control of water system

According to the temperature difference of supply and return water, the signal from temperature sensor will be sent to the refrigerator control room. Thus the automatic control of water system corresponding controls the opening of electric regulable three-way valve to check the by-pass flow. If the by-pass flow is 90 % of one chiller's flow, the signal will be sent to the control room and the control room will automatically (or manually) close a chiller, at the same time a cooling tower will be linkage closed. The above process will achieve energy saving, just like in Figure 4-10.

#### **4.4.3 The automatic control and operation of basement smoke exhaust system**

The basement ventilation system double acts also a smoker exhaust system. In other words, it can put ventilation system and smoke exhaust system closely together and merge them into a complex system. The complex system is usually used as a mechanical ventilation system and it is used as a mechanical smoke exhaust system when there is a fire. Ventilation system and smoke exhaust system use different air ducts. One air duct is designed according to the requirement of the ventilation system, and the other one is designed according to the requirement of the smoke exhaust system. The operations of these two systems are controlled by the opening and closing of valve. Normally the fire damper on smoke exhaust pipe is closed and the fire damper on ventilation pipe is opened. The fan is running to exhaust emission of vehicle and to ensure meeting the health requirements.

When breaking out of fire, the 70°C fire damper on ventilation pipe will be closed. According to the fire alarm or through the control center for fire prevention, the fire damper can be automatically (or manually) opened on the smoker exhaust pipe in the area where there's a fire and to do the smoke exhausting. The automatic control is shown in Figure 4-11.

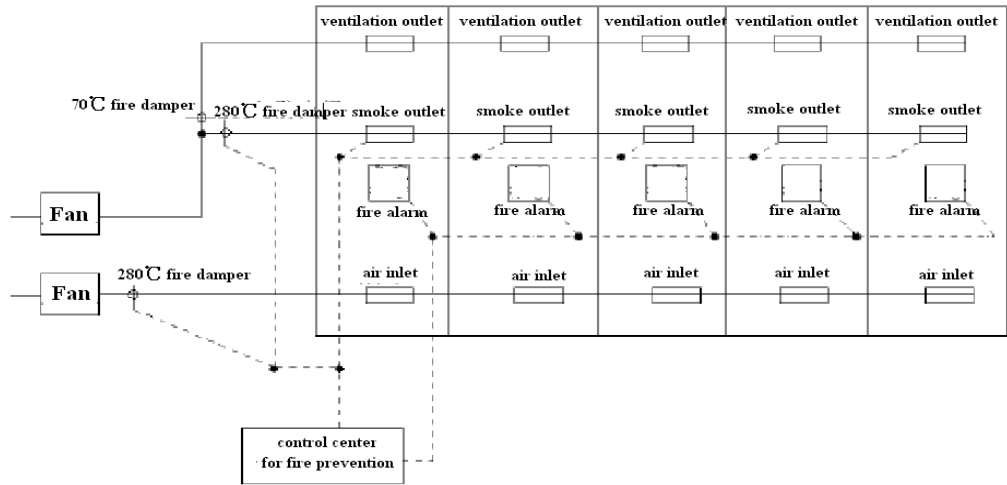


Figure 4-11. Automatic control and operation of basement smoke exhaust system

## 5 Improvement Project Program for Energy Saving in Central Air Conditioning System in Nanchang HKLS

Inverter technology is an effective energy saving technology to reduce the energy consumption of fans and pumps. Therefore, inverter technology is adopted to transform the central air conditioning system and the principle is following:

When the load of air conditioned room is changed, the temperature sensor sends a signal to the inverter. According to the signal, the inverter generates the corresponding frequency and acts on the fan to change the amount of wind through the fan big by speed change. Air conditioning unit fan control system is shown in Figure 5-1.

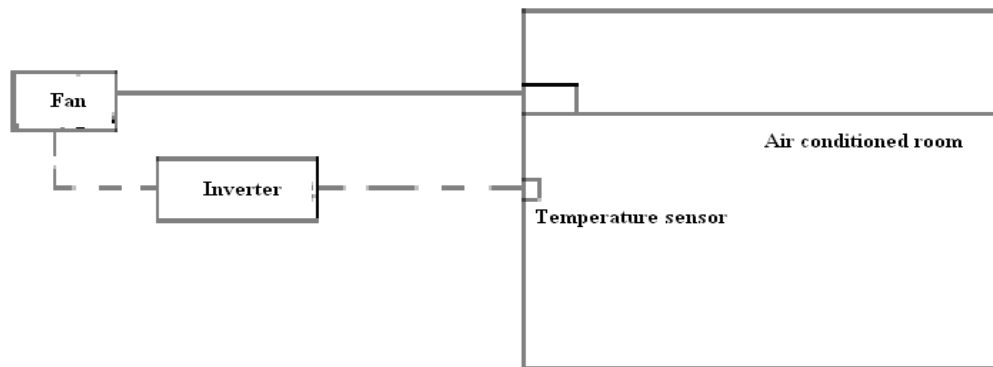


Figure 5-1. Control system of air conditioning unit fan

The cooling water pump or chilled water pump is also used in inverter technology for adjusting. A temperature sensor is added on cooling water or on chilled water return water pipe of air conditioning to detect the signal and send it to inverter. According to this, the inverter compares with the set temperature and feedback value. The inverter will use PID automatically to give appropriate pump speed and flow and will make outlet temperature constant. All of above can ensure maximum efficiency.



The specific working principle is:

When the air conditioning usage amount or temperature is decreased, it will be detected that the temperature of cooling water or chilled water outlet will be decreased or increased. Through the inverter's PID algorithms the pump speed is reduced, then the water flow is reduced too. It should be ensured that the minimum threshold frequency of pump is more than 25 Hz. Then the temperature is ensured to be constant and it is reducing the energy consumption and vice versa.

Diagram is as follows:

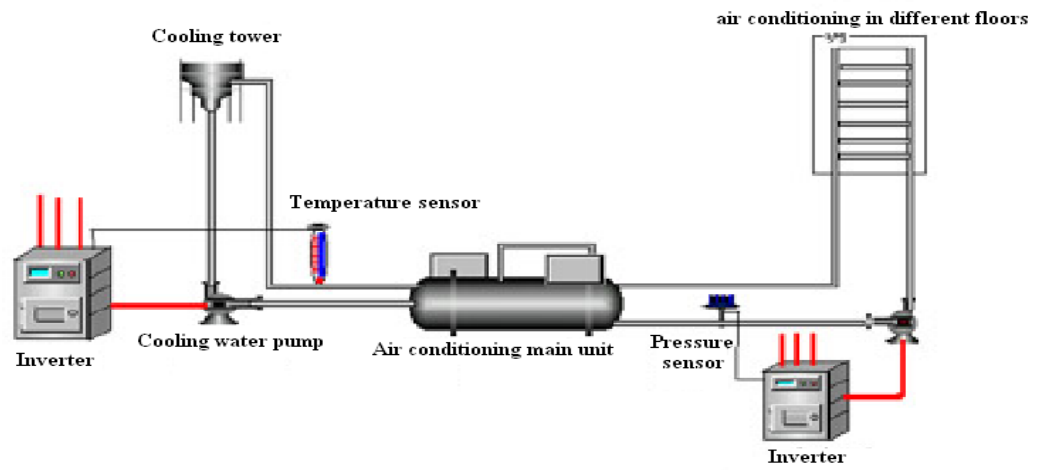


Figure 5-2. Principle of central air conditioning operation

### 5.1 Equipment overview

The fan and pump, their number and installation location in the central air conditioning system of Nanchang HKLS are shown in Table 5-1

Table 5-1 Air processor and pump

ID	Equipment	Model number	Motor Power	Number	Installation location
1	Air processor	YSM-25L-7070-HVCC-L	22kW	1	1F
2	Air processor	YSM-25L-6070-HVCC-R	18.5kW	1	1F
3	Air processor	YSM-25L-6070-HVCC-L	18.5kW	1	2F
4	Air processor	YSM-25L-7080-HVCC-R	30kW	1	2F
5	Chiller water pump		55kW	3	-1F
6	Cooling water pump		75kW	3	-1F
7	Cooling tower fan		7.5kW	3	3F

## 5.2 Improvement plan

Even though there have already be chosen the equipment and the process has been designed, there should be a plan of improvement and systemic segmentation which is suitable of the each floor environment to get the maximum energy saving and efficiency.

### 5.2.1 The equipment of improvement plan for energy saving

For the fans and pumps, Nanchang HKLS takes into account the actual operation situation and energy saving to improve energy saving of following equipments:

- The two air processors in 1<sup>st</sup> floor: Motor powers are 22 kW and 18.5 kW
- The two air processors in 2<sup>nd</sup> floor: Motor powers are 18.5 kW and 30 kW
- The three chiller water pumps in basement: Motor powers are 55 kW (Using two of them and one for preparation)
- Thethree cooling water pumps in basement: Motor powers are 75 kW (Using two of them and one for preparation)
- The one cooling tower fan in 3<sup>rd</sup> floor: Motor power is 7.5 kW
- **The total power of improvement: 356.5 kW**

### 5.2.2 Specific measure

An inverter and temperature controller is added to each fan and pump. The fan speed is controlled by an inverter. The air flow and pump flow are adjusted to achieve energy saving, as shown in Figure 5-3.

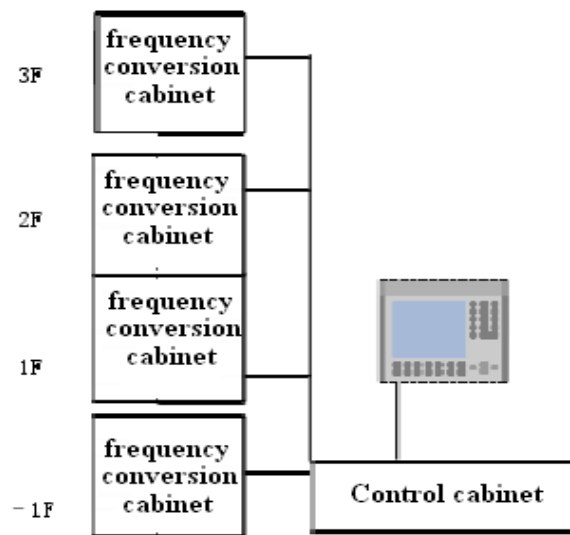


Figure 5-3. Project of collocation

The specific process is:

- To install 2 sets of 75 kW Siemens inverters and one set of inverter control cabinet on the -1F. To install temperature sensor on cooling water return pipe.
- To install 2 sets of 55 kW Siemens inverters and one set of inverter control cabinet on the -1F. To install pressure sensor on chilled water outlet pipe.
- To install 1 set of 22kW and 1set of 18.5 kW Delta inverters and one set of inverter control cabinet on the 1<sup>st</sup> floor. After installing the inverter, it can achieve energy saving and reduce environmental noise can be achieved.

- To install 1 set of 18.5 kW and 1set of 30 kW Delta inverters and one set of inverter control cabinet on the 2<sup>nd</sup> floor. After installing the inverter, it can achieve energy saving and reduce environmental noise can be achieved.
- To install 1 set of 7.5 kW Delta inverter for energy saving of cooling tower fan and to install 1 set of inverter control cabinet on the 3<sup>rd</sup> floor. According to the level of the cooling water temperature, it divides into four levels of automatic control for wind speed.
- To install 1 set of Siemens PLC and an analog input/output module which has built-in EVIEW touch screen for parameter settings. It also has manual/automatic conversion and monitors the fan/pump operation status, system temperature, pressure, speed display and fault records.
- To install the signal cable and power cable.
- To use the control mode: It divides two modes which are power frequency and frequency conversion. In the normal circumstance it is operated by frequency conversion to achieve equipment soft start/ soft stop. When the inverter conks out, it will switch to the power frequency. It should be noted that the contactor of inverter's output side should be disconnected to ensure continuous operation of the air conditioning.

### **5.3 Technical feature**

For this project, Siemens and Delta intelligent inverters which are specifically for HVAC are used. The series has the following advantages:

- Optimized input/ output functions: It meets all the required control and monitoring

functions for a typical HVAC application.

- Automatic optimization of the debugging process: Only 12 basic parameters set can meet all HVAC applications. Expansion parameter can be flexible to meet the application requirements. Debugging is simple and maintenance workload is small.
- Complete electric protection: It can protect overvoltage, undervoltage, overcurrent, motor overheat, ground fault, inverter internal fault and so on.
- Soft start/ soft stop function: It avoids the “water hammer phenomenon” and extends the motor and pump usage time.
- Cable operation: The cable between the motor and the inverter can increase to 150 m without output reactor.
- Energy consumption optimization (ECO): When the set value is reached, the control system will automatically optimize the electrical energy consumption. Therefore, in addition to providing energy saving from speed control, the motor is also running at maximum efficiency.

#### **5.4 Technical and economic analysis**

Due to pump load, torque load is variable and the power consumption of pump motor is the cube of its flow. So if the motor speed is decreased a little, the motor power consumption will be significantly reduced. Frequency conversion technology for energy saving is based on this principle which is achieved through changing the frequency of the motor to achieve the motor frequency change and then changing the pump flow and pressure to save energy.

In the conventional central air conditioning system, due to the circulating pump is

constantly running at rated speed, the load is low and water quantity can not be a corresponding change, the energy will be wasted. If using frequency conversion technology to transform, then it can make quantity of revolving water is changed by automatic adjust pump speed which according to heat load changing. Under the premises which ensure the normal operation of the system, what can reduce energy loss and the effect is obvious. The relationship of pump speed, water quantity and power is shown in Table 5-2.

The energy saving formula of pump speed and flow is:

$$P=K \times n^3 \quad (1)$$

where

$P$  = the power [W]

$K$  = the pump speed [rpm]

$n$  = the water quantity [ $\text{m}^3/\text{h}$ ]

Table 5-2. Relationship of pump speed, water quantity and power by *Formula (1)*

Frequency	Pump speed reduction	Water quantity reduction	Power decrease
45Hz	10%	10%	27.10%
40Hz	20%	20%	48.80%
35Hz	30%	30%	65.70%
30Hz	40%	40%	78.40%

In addition, due to it is need to consider other factors, the central air conditioning engineering design should give a 10-15% margin base on the theoretical design value, and hence to the system consumes more power. If using the frequency technology to transform, the margin can be saved completely.

Under normal circumstances, the energy-saving rate of each motor can be 20-30% or more after using frequency energy saving technology. Conservative estimate is that if the energy-saving rate of motor is 20% and it is running 12 hours per day, then the following

savings can be achieved:

The monthly power consumption of transformation equipment: (30 days per month)

$$12 \text{ hours} \times 30 \text{ days} \times 356.5 \text{ kW} = 128340 \text{ kWh}$$

The monthly saving electricity:

$$128340 \text{ kWh} \times 20\% = 25668 \text{ kWh}$$

The annual saving electricity: (8 months per year for using)

$$25668 \text{ kWh} \times 8 = 205344 \text{ kWh}$$

If the price of one kWh is 0.7 ¥, then **the saving money per year** is :

$$205344 \text{ kWh} \times 0.7 \text{ ¥/kWh} = \mathbf{143740.8 \text{ ¥}} \text{ (about } \mathbf{14374 \text{ €})}$$

One set of frequency energy saving system costs about 230 thousands Yuans. Then it takes about 16 to 20 months to recover from investment costs. It also extends the usage time of pump and reduces the maintenance and repair costs to get more indirect economic benefits.

## 6 Conclusions

In this thesis, the problem and the cause of the problem have been discussed according to the research of the specific practical problem of the traditional energy saving system. Based on the theory of intelligent building management system (IBMS) and the energy-saving central air-conditioning inverter, it can adopt a means of vector control to achieve the integrated use of the technology of dynamic process and the corresponding compensation, constant torque regulator, instantaneous flow of negative interference suppression, and then it can find the solution to improve the central air conditioner equipment and improve HVAC energy saving control system.

Firstly, in the thesis the basic work principle of energy saving of the HVAC was introduced and the way to improve the energy saving process was researched, which is through temperature controller control to the temperature around the inverter. The inverter changes the conversion to regulate the water pump electromotor and the turning speed of the air-blower to control the change of the volume of the wind and flow.

Secondly, due to the disadvantage of the traditional energy saving control system, the energy saving control system is improved through improving the controller design, software design, hardware design and electromagnetic interference design. This way the energy saving system can achieve the optimum control effect and improve the stability of whole system.

Thirdly, the thesis included a case study in energy saving program in Nanchang HongKeLong Supermarket and gave ideas for an improvement project. It was found that the implementation of the energy saving for central air conditioning system can avoid unreasonably inefficient energy use, reduce air conditioning energy consumption and improve energy efficiency.

Finally, through all those methods, the central air conditioning system and its control system can achieve more energy saving and as well as economic and social benefits.



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## **Abbreviations**

**HVAC:** Heating, Ventilation and Air-Conditioning

**VAV:** Variable Air Volume

**RTOS:** Real-Time Operation System

**SCM:** Single Chip Microcontroller

**RLC:** Resistance, Inductance and Capacitance Circuit

**USART:** Universal Synchronous Asynchronous Receiver Transmitter

**PWM:** Pulse-Width Modulation

**EEPROM:** Electrically Erasable Programmable Read Only Memory

**FWD:** Fly-Wheel Diode

**RISC:** Reduced Instruction Set Computing

**DOAS:** Dedicated Outdoor Air System

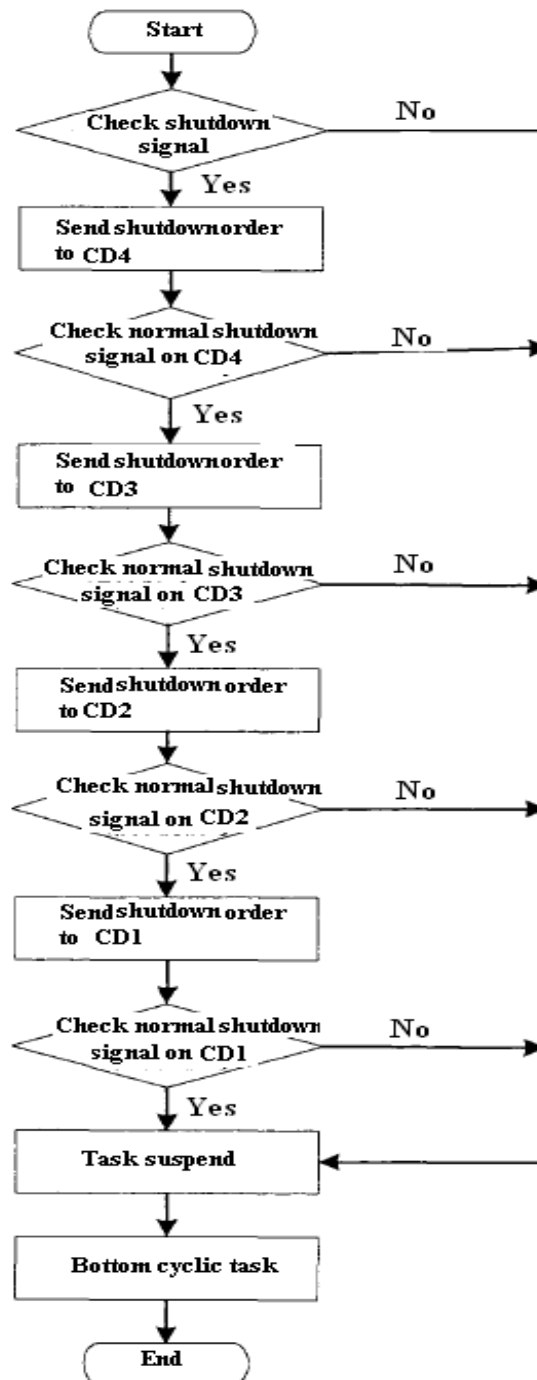
**ECO:** Energy consumption optimization

**IBMS:** Intelligent Building Management System

## Appendices

- Appendix 1 SD shutdown process*
- Appendix 2 Control flow of chiller*
- Appendix 3 Chilled pump interrupt processing flow*
- Appendix 4 Cooling tower control flow*
- Appendix 5 PWM output circuit*
- Appendix 6 Minimum CPU circuit in node controller*
- Appendix 7 Low-pass filter circuit*
- Appendix 8 RS-485 communication circuit*
- Appendix 9 DO relay drive circuit*
- Appendix 10 DI detection circuit*
- Appendix 11 Minimum CPU circuit of equipment room controller*
- Appendix 12 Ethernet communication module circuit diagram*

## Appendix 1



Symbol Description:

SD = frozen-stop service manager;

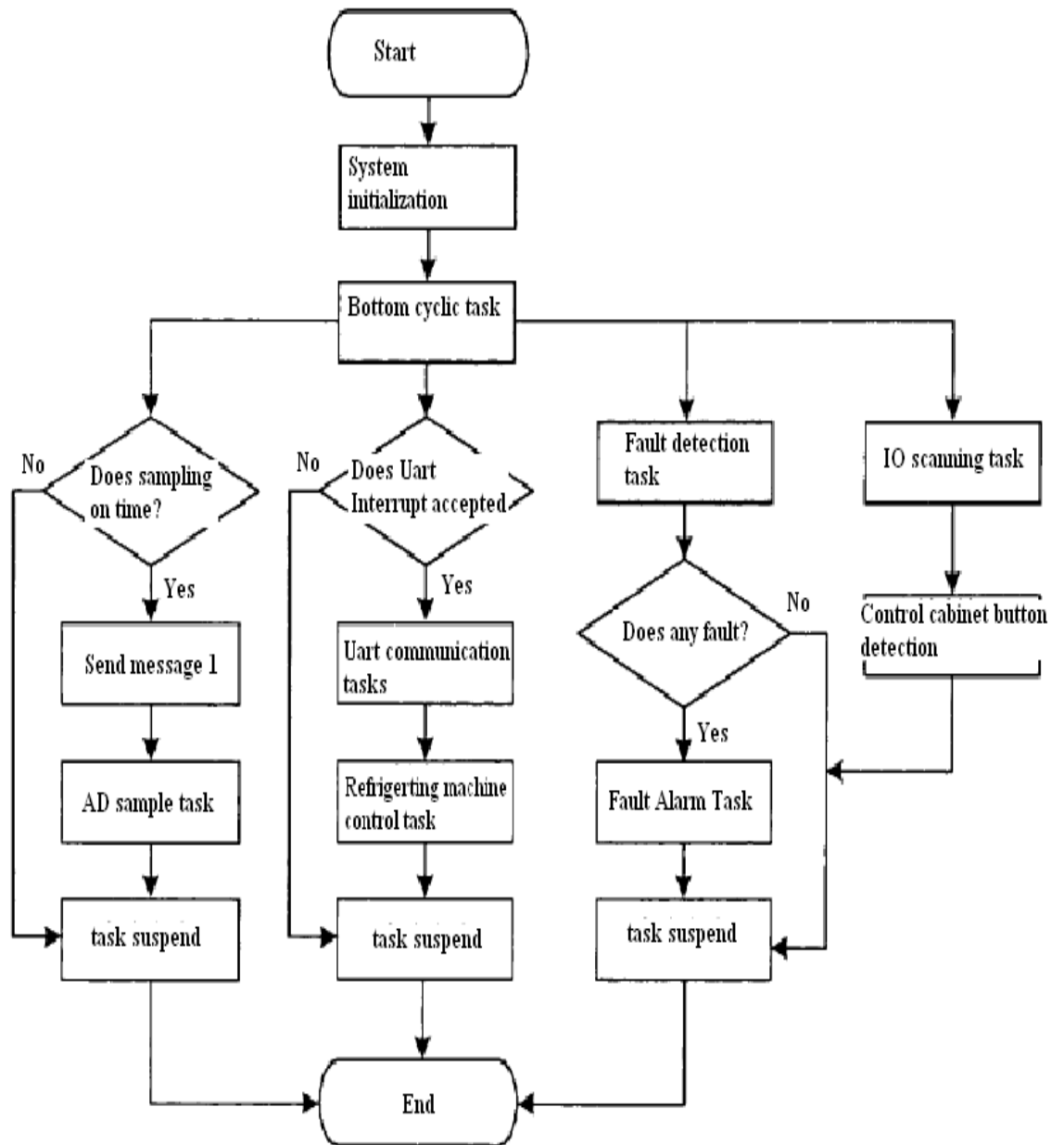
CD2 = cooling tower controller;

CD4 = water chiller controller

CD1 = cooling pump controller;

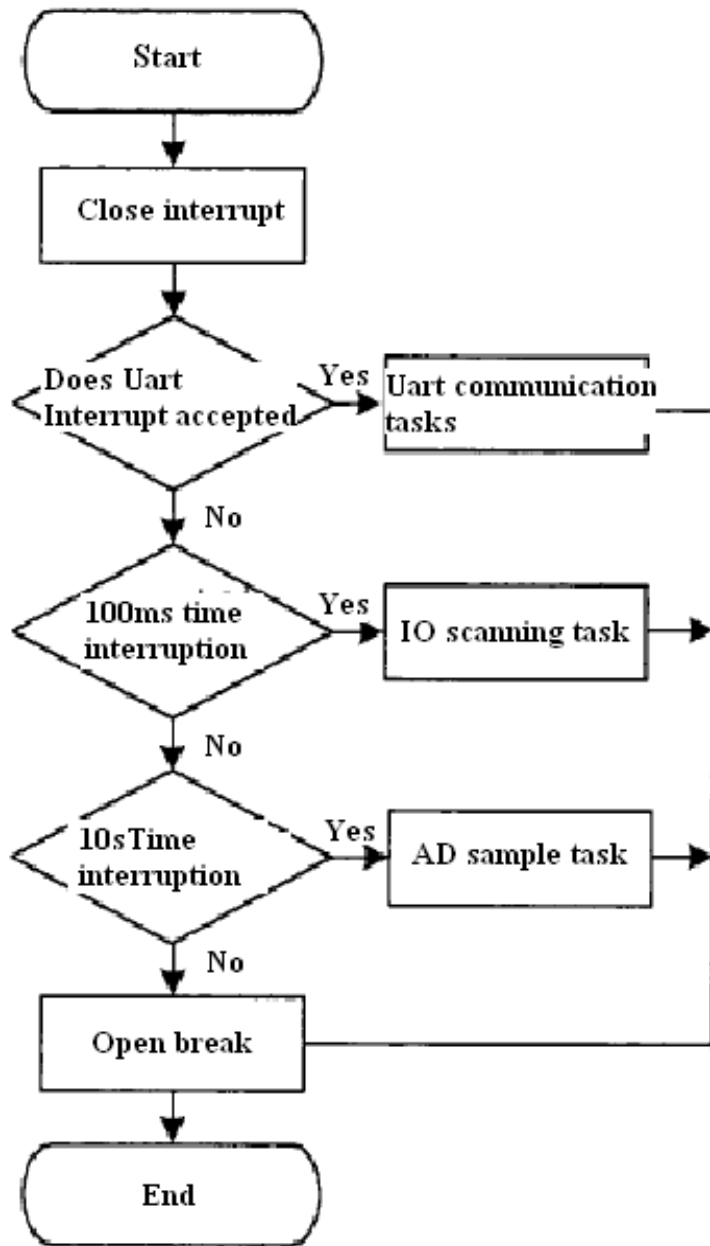
CD3 = freezing pump controller;

*Appendix 2*

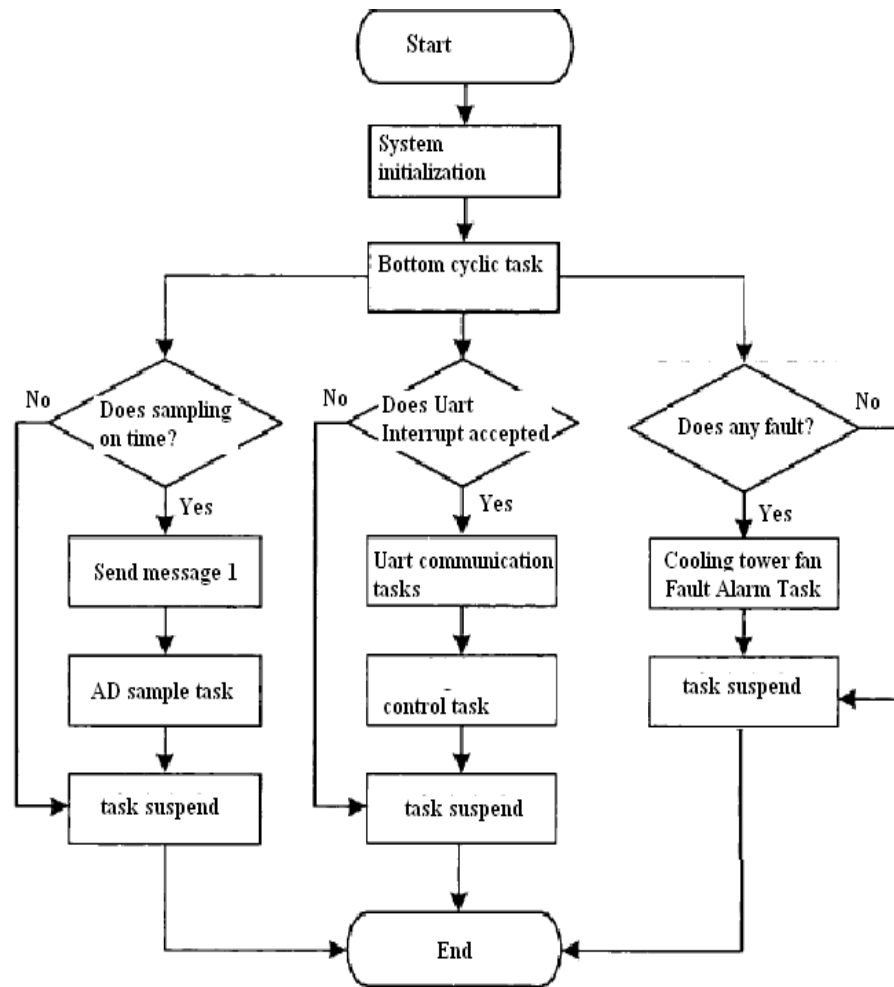




*Appendix 3*

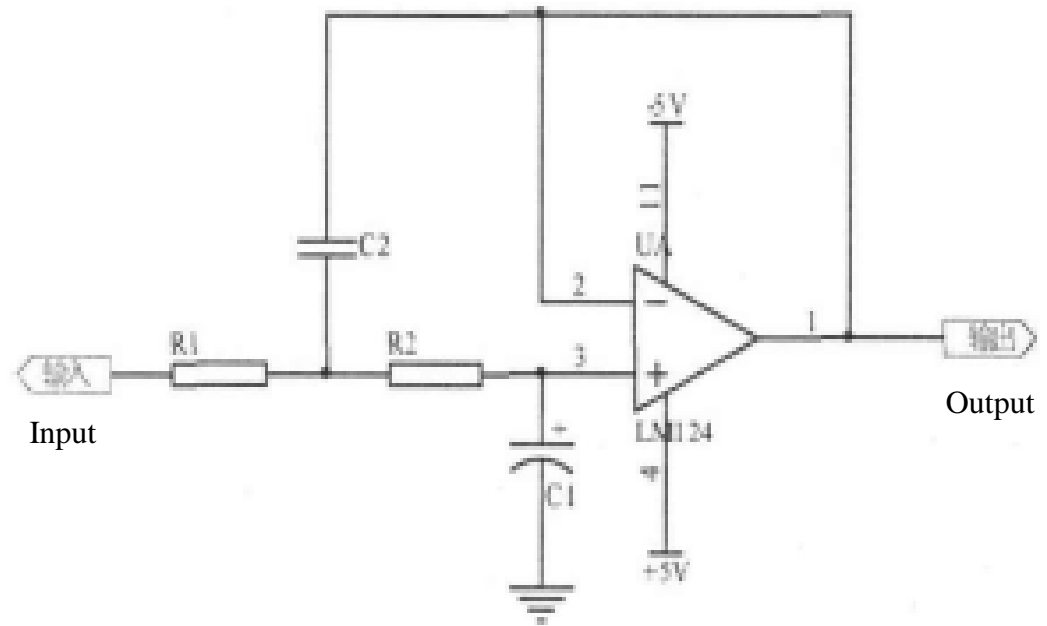


*Appendix 4*

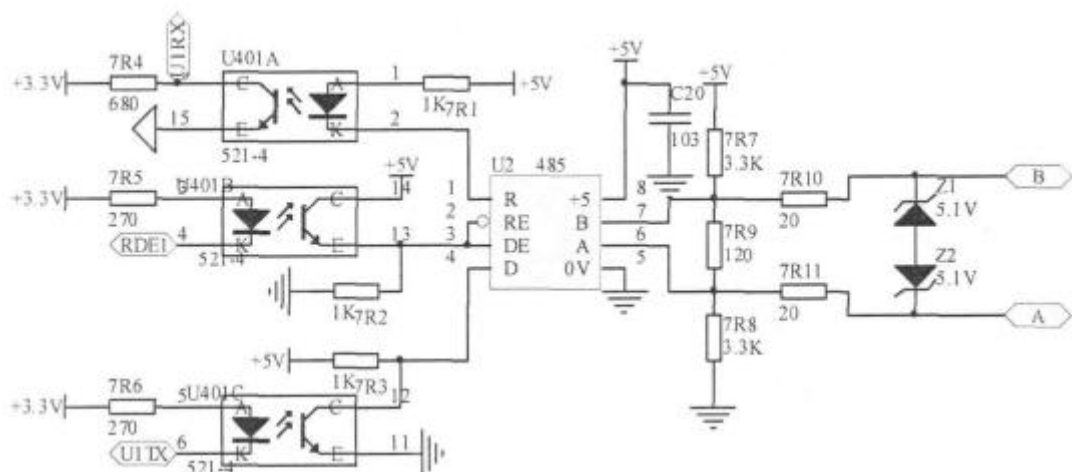




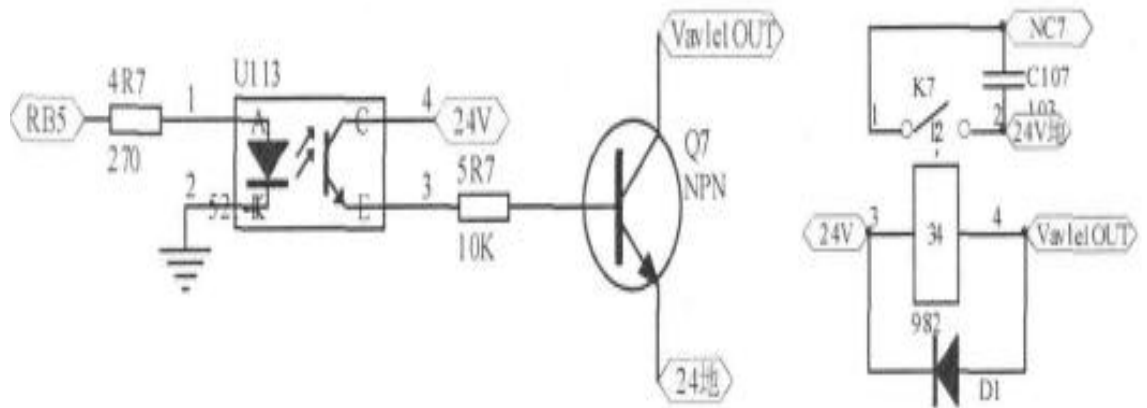
## Appendix 7



## Appendix 8



### Appendix 9



### Appendix 10

