Direct Digital Control in Air Conditioning Systems for Energy Efficiency[1]

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Abstract: With the rapid development of Intelligent Buildings (IB), the Building Automation System (BAS) has come to control and manage the equipment in the building more and more scientifically, economically and rationally, which can not only raise the function and the level of the building, but also save energy. At present, air-conditioning design in internal commercial buildings is becoming more complex and enormous. The proportion of air conditioning systems in the whole building is getting larger. In order to control and manage the air-conditioning systems effectively and take full use of energy-saving technology, we apply computer control to the system of air automation control. This paper discusses direct digital control (DDC) in the air conditioning system in buildings.

Keywords: Direct Digital Control (DDC), energy saving in air conditioning system, DDC automatic control system

1 INTRODUCTION

Economic development, civil, public and commercial building central air conditioner Popularizations bring a serious energy consumption problem. The more the amount of air conditioner in use, the more electricity expensed, it leads to the lack of electricity and limit the municipal use of electricity in summer. It is well known, (heating, ventilation and air conditioning) the system consumes approximately about 50%~60% the whole building consumption in the intelligent building. Especially the freezes unit, the cooling tower, the circulating water pump and the air conditioning unit and the fresh air unit, consume most of the energy. In order to control and manage the air-conditioning system effectively, and take full use of energy-saving technology, we apply computer control to the system of air automation control. DDC (Direct digital control), as the name implies, it involves direct digital communication between sensors, controllers, and actuators. DDC systems can be controlled by microprocessors or computers, which allow for more flexibility in control algorithms and also allows monitored remotely.

2. DDC CONTROL SYSTEM

2.1 Definition

Direct Digital Control (DDC) is a type of energy management system. DDC is a form of closed loop control. A loop is a sequence of instructions, which are executed until a condition is satisfied. The term “Direct” means a microprocessor is directly in the control loop. The control is accomplished by digital electronics that read or control both digital and analog signals. The three main benefits of DDC are improved operation, improved control effectiveness and increased energy efficiency.

2.2 Control Basics

Control in a HVAC system involves measuring and collecting data, processing the information and causing a control action. The components of system control include the sensors, the controllers, the control loops and the data types. Sensors measure controlled mediums or other controlled inputs in an accurate and repeatable manner. Sensors can measure temperature, pressure, relative humidity, time of day, electrical demand condition, air volume, fluid flow, electric current, fire, smoke, high/low limits etc.

The controller compares the inputs from sensors with a set of instructions such as set point, throttles

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range and required action. Then the controller produces an output signal that will cause the required action to satisfy the condition.

A control loop is the interaction between the sensors, the controller and the control the devices. An example of a HVAC control loop would be indoor air temperature regulation. The sensor measures the indoor air temperature, and outputs the data. The controller processes the data and sends the output to the controlled devices causing the required action. Controlled devices may include but are not limited to valve operators, damper operators, electric relays, fans, pumps, compressors and variable speed drives.

Data types are digital, analog and accumulating. Digital (binary) data is an integer, a 0 or 1, and usually represents a state or condition such as on or off. Analog data are represented by a numeric or decimal number defining a varying electrical input that is a function of some variable. A numeric or decimal number that is the resulting sum of some function also represents accumulating data. This type of data is sometimes called a pulse input.

3 THE MAIN FUNCTION OF THE ENERGY EFFECTIVE SOFTWARE

The energy effective software can use the DDC control system control device effectively, creates the comfortable indoor environments, achieve the energy conservation the goal. The Control software includes the operation software and the application software.

3.1 Software Characteristics

Three common approaches are used to program the logic of DDC systems. They are line-programming, template or menu-based programming and graphical or block programming.

Line programming systems use Basic or FORTRAN languages with HVAC subroutines. Being familiar with computer programming is helpful in understanding and writing logic for HVAC applications.

Menu-driven database or template/tabular programming system use templates for common HVAC logical functions. These templates contain the detailed parameters necessary for each logical program block to function. Dataflow, or how one program block is connected to another, is programmed into each template. In this type of software, less programming experience is required. Graphical or block programming is an extension of template/tabular programming. Graphical representations of the individual function blocks are depicted using symbols connected by lines that represent the data flow.

The process is depicted with symbols as on electrical schematics and pneumatic control diagrams. Graphical diagrams are created and the detailed data is entered in background menus or screens. This programming is very user friendly and virtually anyone familiar with HVAC systems can understand this type of programming.

3.2 The Energy Effective Software

It is uses for to each item of specialized equipment to carry on the control the software.

a) Direct digital control software, provides including P, PI, the PID control, namely proportional control, proportion differential control, proportion differential integral control, as well as self-adaptive functions and so on.

b) Energy management and control system

Energy management and control system (EMCS) technology has evolved over the past three decades from pneumatic and mechanical devices to direct digital controls (DDC) or computer-based controllers and systems. Today's EMCS systems consist of electronic devices with microprocessors and communication capabilities and utilize widespread use of powerful, low-cost microprocessors and standard cabling communication protocols.

4 DDC CONTROL SYSTEM IN AIR-CONDITIONING SYSTEM

4.1 DDC in the Air-handing Unit of Air Conditioning System

Figure1 is DDC control system in the air-handing unit of air-conditioning system. DDC controller must fulfill the main functions:

1）The temperature and humidity monitor and display of air-condition zone.

2) The temperature and humidity automation of

air-condition zone.

3) The temperature and humidity monitor and display of outside air.

4) Supply air and return air fan state (on or off) display.

5) Supply air and return air fan start and stop control.

6) Supply air and return air fan overload alarm.

7) Communication with the control center and send the device state or receive the order from control center.

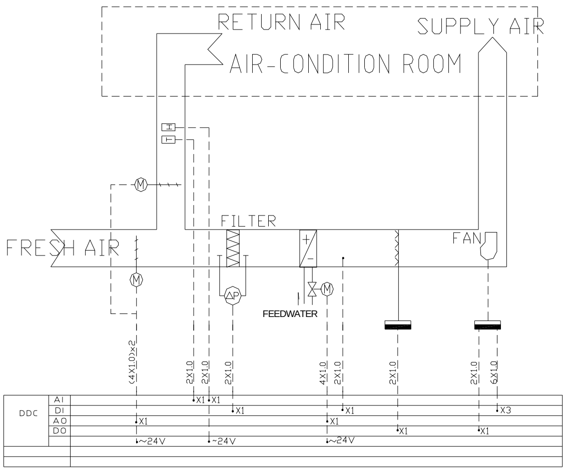
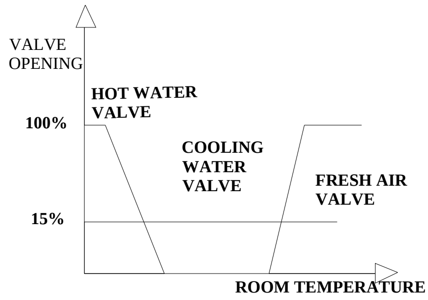


Fig.1 DDC in the air-handing unit of air conditioning system

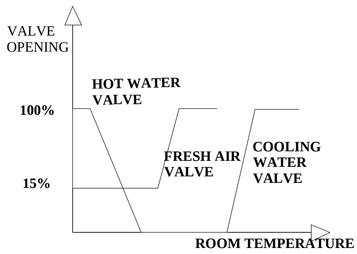
4.2 The Enthalpy Value Adjustment

Enthalpy value adjustment is comparing the room air enthalpy I_N and outside room enthalpy I_W. The DDC controller calculates the room air enthalpy I_N according to the temperature and humidity signals. The signal is sent from temperature sensor and humidity sensor in the room. The DDC controller calculates the room air enthalpy I_W according to the temperature and humidity signal. The signal is sent from temperature sensor and humidity sensor outside the room. Then according to the indoor temperature value, DDC send control command to drive digital electromotor. The electromotor control return air valve and fresh air valve opening degree and change the mixture ratio of the fresh air and return air.

Figure 2 is the enthalpy controls the process. May see from Figure, in order to save energy, the enthalpy value control must use fresh air fully (i.e. 100% fresh air) When $I_N > I_W$. When $I_N < I_W$, the fresh air valve keeps the smallest opening position, guaranteed in the supply air has 15% fresh air in order to satisfies the sanitation request.



$I_N < I_W$



$I_N > I_W$

Fig.2 The enthalpy control the process

4.3 Start/Stop Optimization

When start/stop equipment to prepare a zone for occupancy? Start too late and occupants might be too hot or too cold for a while when they are first in the zone. Start too early and you waste energy conditioning unoccupied zones. What’s more, you may need to constantly adjust the start schedule for seasonal and building factors.

Start/stop optimization or temperature/time optimization, as it is sometimes referred to, is an improvement over simple setup/setbacks. Setup/setbacks are based on time-of-day, while the start/stop optimization strategy accounts for outdoor-air conditions and can include thermal storage of building mass to determine when to startup and setback the HVAC system operation. The optimized stop time permits certain HVAC systems (e.g., chillers and boilers) to be shutdown before the end of the occupied period (e.g., 10 to 15 minutes) and allows the zone temperature to float within acceptable comfort levels. Similarly, the optimized start time permits certain HVAC systems (e.g., boilers and chillers) to start just in time to allow for the zone conditions to reach the acceptable range just when the zone begins to be occupied.

4.4 The Temperature Control

The temperature control is most basic control in the air-conditioning. In DDC control system, signal that receive from temperature sensor send to DDC controller through two analog signal input port. After sampling, A/D will transform analog the temperature signal to the digital signal, with the set temperature point comparison to obtain the deviation. After DDC calculation, outputs the digital signal to control device through bus. The digital signal drives digital electric motor in the winter, which controls hot water valve opening degree and adjust hot water flow to enter to the air heater, in order to meet the heat load change. In transition season, then drives the digital electromotor, on the one hand controls return air valve and the fresh air valve opening degree, adjusts the fresh air and return air proportion, on the other hand control cold water valve opening degree, adjusts cold water flow to enter surface cooler, modulates to meet the room load. In summer, DDC must control fresh, returns air valve opening degree, keeps the fresh air volume in 15%, meanwhile through electric motor controls cold water valve opening degree, controls cold water volume.

In DDC controller, you can select appropriate control algorithm according what you control, such as the fresh air temperature compensation control, automatic adaptive optimum PID parameter control or fuzzy control and so on.

4.5 Fan Control

In air conditioning, the fan consumes most of the energy in air-handle unit. Therefore it is necessary to cut down the fan rotate speed when room load at low level. Because the supply air volume is along with the fan rotate speed, controlling the transducer's frequency can control the supply air volume. First collect all require air volume from each DDC, then get the total air volume and send analog signal (0~10V) to control the transducer frequency according to the relation between transducer frequency and supply air volume. Figure 4 is the relation between transducer frequency and analog voltage.

4.6 Energy Saving Experiment

In order to test the effect of the DDC system, we recorded the cost of the air condition system in the same building. The cost is air-condition system consumes the electricity bill every month. Figure1 is the cost of from May to Oct of 2004 and 2005. We can know DDC system can reduce cost of air-condition system obviously.

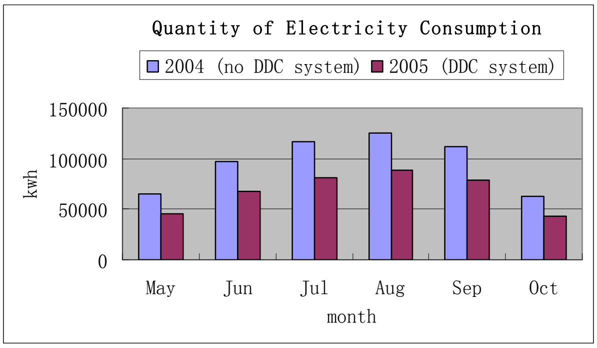


Fig. 3 The cost of the air-conditioning system

5 CONCLUSION

With a DDC system, the savings in gas and electrical consumption can range from 20% to 50%. Savings are also achieved in the maintenance of DDC systems compared to pneumatic systems. Pneumatic systems require constant monitoring and recalibration due to drifting. Drifting, or falling out of calibration, occurs in pneumatic equipment because of the interaction between air and mechanical devices. Drifting will not occur in DDC systems because digital signals, which are more accurate and reliable, have replaced the old pneumatic controls. System maintenance savings can be estimated at 40% or better.

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