A Study on static-pressure control method of VAV System in Intelligent Building

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INTRODUCTION

As the development of country's economic and the improvement of living-standard in China, there are more and more buildings which are making use of the VAV(Variable Air Volume) Air-Conditioning System to make people comfortable. The Intelligent Building is making use of system integration method to combine with the Intelligence Computer Art, Communication Art, Information Art and Architecture Art in an organic way, which has the characteristics of more subjects, more technologies, high technology synthesis and so on by the automatic monitoring to the equipment, the administration to the information resources and the information service to the user and to their Building's optimization grouping, with reasonableness, safety, high-effect, comfortable, convenient, nimble characteristics to integrate and adapt the information and social demand.

In the 1960s, the Variable Air Volume Air-Conditioning System VAV was born in America. The basic principal of the VAV Air-Conditioning System is simple, which is to satisfy the room's variable load by changing the airflow supplied to the room. As the VAV air-conditioning system is running in partial load most of the time, it can improve the device and system's energy utilization by reducing the ventilator's energy consumption of decreasing the airflow capacity. At present, the usage rate of West Country's VAV air-conditioning system in high Building is surpass 90 percent, however in China, the application of VAV air-conditioning system will be more and more as the serious problem of the High Building's energy consumption. VAV air-conditioning system is composed of AHU, fresh air/exhaust air/supply air/back air duct, VAV BOX, room temperature controller, VAV BOX is the most important part of this system.

VAV AIR-CONDITIONING SYSTEM PLATFORM TASK

The introduction of the system platform

This task's VAV system mainly adopts the WEBCTRL platform as shown in *Fig 1*. Following the agreement of BACnet protocol, under the condition of compatibility of the speed, cost and future frequency width extend ability, ALC corporation's control ware network adopts the structure of three layers, which provide different controller categories including the upper computer machine, router, the controller of I/O nods, integrated controller and the local implement wares and sensors in different layers. The controller of I/O nods is divided into three kinds which is corresponding to the three layer distribution structure, for example, the structure and application of cooling/heating unit, AHU, terminal devices and so on.

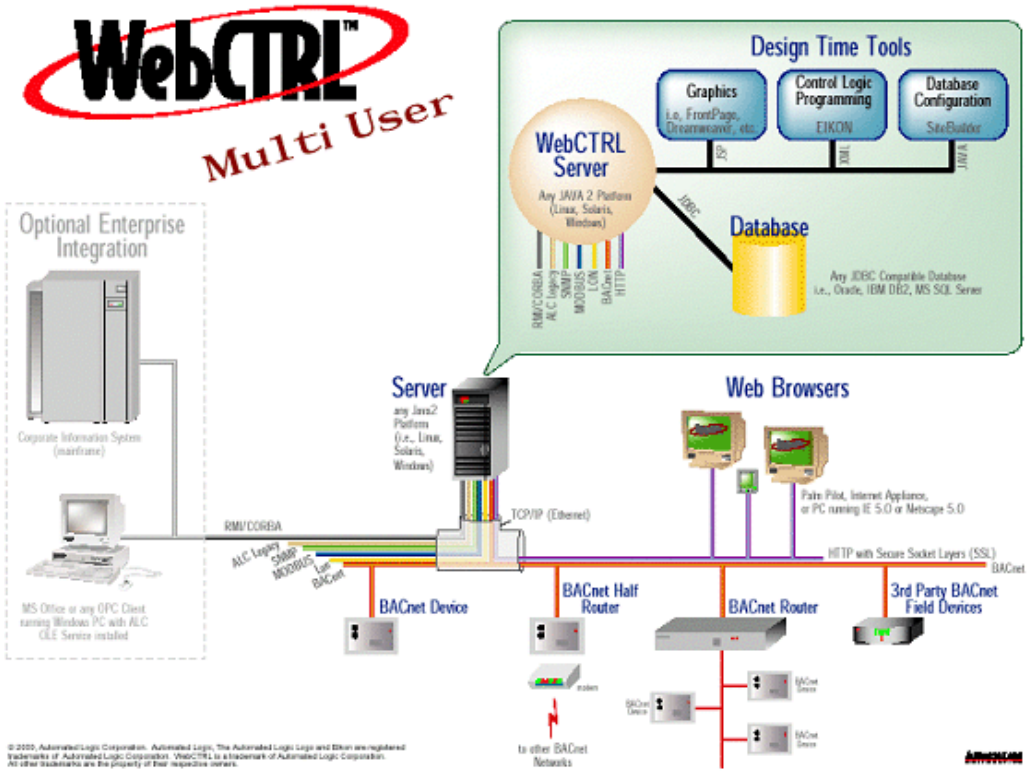

Fig 1 WebCtrl system structure picture

System Software

Building Automation Control System of ALC/WebCTRL™ is composed of four parts:
(1) WebCTRL Server software it takes charge with the various controllers and network station communication as well as data exchange.
(2) SiteBuilder it is the frame tool of the system database that could quickly set up the system structure.
(3) EIKON it is the tool of graphic compiler that is used for compiling device control programs
(4) MS FrontPage2000 and its accessories are mainly used for designing the dynamic graphics and carrying out the controls and data displacements.

Here the compiler tool EIKON is the most advanced graphic compiler in the industry. By clicking the button, it can make complicated control algorithm, diagnosis faults, which can test the performance of the control programs with the real-time or simulative running parameters. EIKON is not adopting line-by-line and abstruse code so that to make the control programs easily understood

System Hardware

The hardwares of the ALC/WebCTRL™ 's Building Automation Control System are as follows:
(1) Network Router LGE
LGE is the high performance net router, which is mainly used for M series, S series, UNI, WebPRTL serial control wares to communicate with the Ethernet. LGE is based on the 10Base-T Ethernet, which is mainly taken charge for the control ware subnet and sending

messages between other net router and the upper computer machine's software WebCTRL Server.

(2) M serial locale control ware
M serial control ware is suit for multi-device control, which is one part of ALC corporation 's WebCTRL^{TM} system. It includes the S serial and U serial control wares. M serial control ware has the firmly structure and separate running ability, which is suit for multi-device application occasion.

(3) S serial locale control ware
S serial control ware is the mainly single control device, which provides the high reliability and strong design that could make the controllers accommodate various conditions, even the roof installation.

(4) Subnet locale control wares
Subnet locale control ware is mainly the U serial control ware, which has two types UNI/16 and UNI/32 at present. They are both the network router that is used for communicating with the BACnet MS/TP standard protocol control wares, which is based on the high 156K baud among the ARCnet Building Automation's communication.

The software's energy-saving device

WebCTRL system has obvious characteristics in energy-saving aspects, which makes the energy-saving devices achieve less energy consumption in a certain degree under the condition of indoor comfortable environment.

(1) Space Temperature Control (STC)
According to the cooling season or heating season, working time or free time and the condition of peak value, it will ascertain the room's temperature control value. And seven kinds of colors will show the room's temperature and PMV.

(2) TOD (Time of Day Scheduling)
Time schedule is to prescribe the building or district under a certain state, for example in the process of being used, set the device's on/off time, make the device run effectively. It can also set separate device or the device group's running schedule. Time schedule has normal, free time super time three kinds of PRI that are convenient for user to manage.
(3)TLO (Timed Local Override)
The Operating System has set the locale super control, which will allow the user to surpass the program control in requiring time and lock the import or export values.

(4) OSS (Optimum Start/Stop)
Optimum Start/Stop is mainly used to complete transition from the free time to working time. Under the normal outdoor condition, optimum start/stop will follow the temperature ascending velocity and the descending velocity of the cooling room considering to the outdoor temperature and enclosure structure's heat-gained and heat-lost coefficient. It will also assure the indoor's PMV and effectively reduce the device's running time.

(5) STO (Source Temperature Optimization)
According to the building's district demand, it will allow the temperature setting value of the cooling/ heating chain's different devices (air-conditioning unit, chiller unit, boiler device) to reset in the user's prescribed scale. The calculation of the practical setting value is processing according to the heating or cooling demand times of the present device or district feedback. In every updating period, STO program will check the network whether each device will absorb the additive heat or cool quantity from their cooling/ heating source.

(6) DL (Demand Limiting)

It will measure the using situation of the building's electric power, which will divide three electric demand grades. According to the electric demand grades to modify the temperature setting value, it will assure the system just to reduce the building's PMV instead of not be paralysis.

(7) DNS (Day/Night Setback

It allows the room's temperature to descend or ascend in a certain pre-establish scale in free time. If it reached any end of the DNS scale, heating (cooling) will start up until the room's temperature return the DNS scale.

THE EXPATIATION OF THE VAV AIR-CONDITIONING SYSTEM'S CONTROL SCHEME

The test condition of the task

This task adopts the typical VAV air-conditioning system control scheme, contrast to the full air-conditioning system, the main characteristic of which is installing a VAV terminal device in each room. This terminal device is actually a valve by which could increase or reduce the airflow supplied to the room in order to achieve separately regulation to various room.

According to the Intelligent VAV control project of this task, its terminal adopts pressure-independent control method, which is lack of plus-pressure ventilator and terminal reheat device. So the hole system only has the summer condition, the main control scheme of this task.

Intelligent temperature sensor will transfer the setting value and measuring value to the locale controller in order to compare the two values of the heat demand or cool demand. Then the airflow control module will calculate the room's airflow set point, and compare it to the actual measured value by the airflow measuring device, regulate the valve's opening and satisfy the room's load request. The valve's minimum opening should satisfy the minimum needs of the room's ventilation, terminal heating or cooling needs and transfer the limit opening value to the upper AHU through the control network. The valve's minimum opening value and the limit opening value are the foundation of resetting supply air temperature. The actual measured value is the foundation of controlling the back airflow of AHU.

Stable static pressure control scheme

At present, the stable static pressure control method is the normally used VAV system control way, which is simple and feasible. However, its fan energy consumption is high so that the terminal valve state's pressure distribution and the static pressure setting value are not easy to set in applicable engineering. Or else it will reduce the energy-saving effect and be likely to appear increscent noise phenomena.

Variable static pressure control scheme

Variable static pressure control method is the best energy-saving way. Although Variable static pressure control method could economize fan's energy consumption in the farthest degree, the control method is very complex and different to carry out because the system has increased the valve-opening sensor, which should be feedback to the static pressure controller through the communication network. The control device provided by the market doesn't offer the variable static pressure control algorithm. As a result, it needs the engineers to compile and debug in the locale case, so the workload is too heavy. Comparing to the stable static pressure control method, this kind of control method also adopts pressure control, which has

the same problem of the system stability. This kind of scheme is suit for large-scale public building that adopts Building Automation System.

TRAV terminal regulation scheme

According to the advanced theory abroad, American writer T.B.Hartman has brought forward TRAV (Terminal Regulated Air Volume) control method, which creates comfortable environment by regulating the airflow. Based on the practical airflow demand, TRAV control method adopts more advanced control software to carry out the ventilator control. The concrete control method of this control system is as follows, according to the three VAV terminal airflow's differences between the total measuring value and airflow setting value, it will follow PID algorithm to control the frequency ventilator and ventilator's airflow in the opposite direction and forward feedback.

VAV TERMINAL CONTROL SCHEME

The total airflow control scheme

Based on the pressure-independent VAV terminals, the total airflow control method is a newly simple and feasible control method. According to the relation between the total airflow and ventilator's rotate speed, it can regulate the ventilator's rotate speed. The energy-saving effect is between the stable static pressure and variable pressure method. As the control way does not adopt pressure control, the control system which is a practical fan airflow control way is stable.

The total airflow control method is to calculate the ventilator's demand rotate speed in a certain degree, which is different from the typical feedback control. However, the setting airflow does not immediately set to the satisfied future airflow load (that is stable airflow) after the room's load is changed. Then the setting airflow is the middle control quantum that is gradually stabilized room temperature, which is integrated through room's temperature departure.

As a result, the ventilator's rotate speed of the total airflow control method will immediately regulate to the stable speed and not change after the room's load varies. As a matter of fact, the total airflow control method is a kind of dominating ventilator's rotate speed control method according to the room's temperature departure regulated by the PID controller.

Cooling On Demand scheme

The meaning of Cooling on demand is to carry out the energy-saving control to the cool supply equipment under the satisfying user's cooling on demand. Control system makes use of network control technique, supervises the terminal equipment, cool water user and cool source. And the cooling on demand and using cool time to request are taken on the catenulate delivery, it is shown in *Fig 2*.

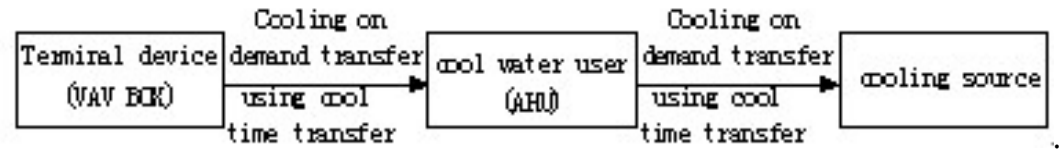

Fig2 Cooling on demand control frame picture

Terminal VAV BOX calculates the cooling on demand and the cool time request according to the temperature of the control area and the Opening situation of the valve, transfers it to the superior air-conditioning unit; the air-conditioning unit sets up the supply air temperature according to subordinate cooling on demand, then it ascertains whether or not to start up the air-conditioning unit and suggests using cold time request by the superior cooling source according to the request of the subordinate cooling time; it refers to the real supply air temperature and the duct water valve's opening aperture situation to calculate the cooling demand of the superior cooling source; cooling source makes the statistic of all consumer's cooling on demand and the request of using cooling time, comes to ascertain whether or not to startup a cooling air-conditioning unit, resets the chilled water pump's supply water temperature, or adjusts compression pump again.

Terminal regulate control air volume（TRAV）is to adopt advanced control software to directly control the supply air fan according to the air-conditioning room's working condition, terminal device's real time air-flow demand and air valve's switch state. The concrete control mode is that according to the VAV terminal air-flow's different value between the total measure value and the air-flow's total set point value, it will control the fan frequency transformer and the fan airflow to regulate in the opposite direction feedback on the base of the PID algorithm. It collects VAV terminal device's valve numbers of the full-opened and full-closed, if all valves are full-closed, the fan's frequency transformer will carry out the opposite direction feedback regulation, that is to diminish the frequency of the Frequency Transformer; If at least one valve is full-opened, the fan's frequency transformer will carry out the positive direction feedback regulation. [3] The terminal regulation control theory is shown in *Fig 3*.

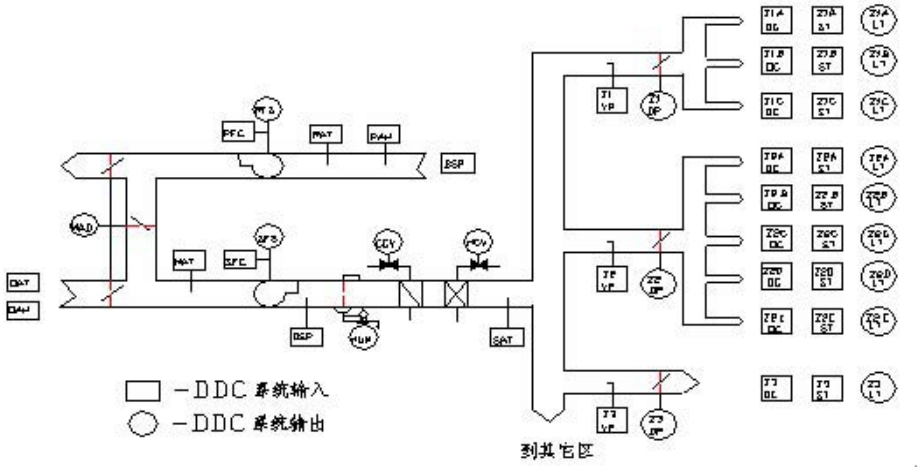

Fig 3 Terminal regulated control theory picture.
LT-use button, ST-indoor intelligent temperature sensor, OC-occupational sensor, DP-air valve, VP-airflow sensor, SAT-ventilation temperature sensor, CCV-cooling water valve, HCV-heating water valve,HUM- humidifier valve, OAT/OAH-fresh air/ temperature humidifier sensor, RAT/RAH-return air temperature humidifier sensor

Variable supply air temperature control scheme

Here we elementary set the Variable supply air temperature control scheme, the develop control program in our task, the AHU control unit could adopt cooling optimization algorithm:

(1) The initial supply air temperature set value is 12.5℃(summer condition) and the minimum value is 11.5℃ and the maximum value is 22℃

(2) If the 30 percent of the opening of the VAV terminal (Damper value)which is running has reached the maximal opening and continuing 5 min, it will regulate the cold water valve and all terminals of the unit's service will reduce 0.5℃.
(3) If the 30 percent of the opening of the VAV terminal (Damper value)which is running has reached the minimal opening and continuing 5 min, it will regulate the cold water valve and all terminals of the unit's service will reduce 0.5℃.
(4) AHU control unit will transit from ir-refrigeration condition to refrigeration condition, the set point's control algorithm will change from the refrigeration condition set point in a speed of 0.5℃ per minute.
(5) AHU control unit will transit from refrigeration condition to ir-refrigeration condition, the set point's control algorithm will change from the refrigeration condition set point in a speed of 0.5℃ per minute.
(6) If the supply air temperature is 2.5℃lower than the set point of the supply air temperature(in case of 0.5℃transfer hysteresis) in a continuously 5min, AHU will control it to bring a alarm signal, which will be effective after the ventilator is continuously running for 30 min.
(7) If the supply air temperature is 2.5℃higher than the set point of the supply air temperature(in case of 0.5℃transfer hysteresis) in a continuously 5min, AHU will control it to bring a alarm signal, which will be effective after the ventilator is continuously running for 30 min.

Software testing result

Heat district testing result

Based on the BACnet protocol, this Building Automation Platform software organizes and develops the control algorithm, and carries out software simulation test and physical system's debugging experiment according to TROX single-duct pressure-independent VAV terminal under the condition of Building Environment and Intelligence Laboratory of Beijing Union University. At the same time, it adopts the ALC Corporation's U341+ control ware and the test result is shown in *Fig 4*. From the chart, we can see that the indoor temperature's trend is close to 23.8 after the air-conditioning system setup 20min. And after 55min the result is close to the set point and the dynamic departure reduced markedly. It has proved that the control algorithm is feasible and the algorithm has higher consult values.

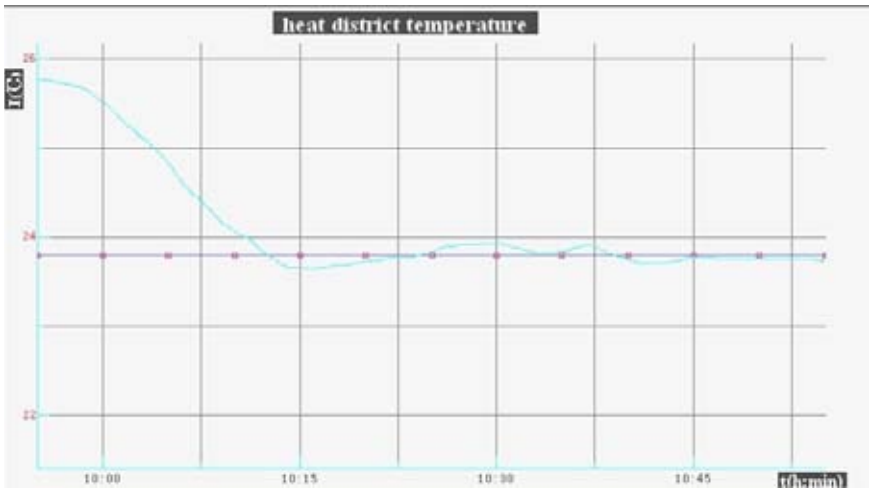

Fig 4 VAV Air-conditioning room's inspecting picture

Airflow and static pressure inspecting result

VAVBox terminal airflow device has measured the variable curve at 14:48-14:58 one day afternoon, as shown in *Fig 5*, of which the airflow is 3250 m^3/h; ventilator static device has measured the variable curve at 14:40-14:48 one day afternoon, as shown in *Fig 6*, of which the mean static pressure is 265pa; the system terminal static pressure device has measured the variable curve at 15:20-15:28 one day afternoon, as shown in *Fig 7*, of which the mean static pressure is 40pa.

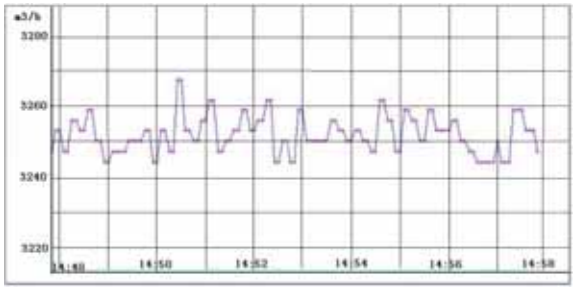

Fig 5 VAVBOX terminal airflow inspecting picture.

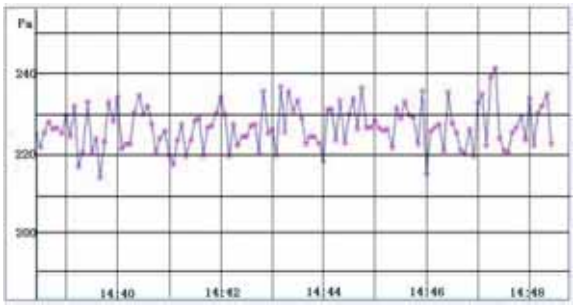

Fig 6 ventilator static pressure inspecting picture.

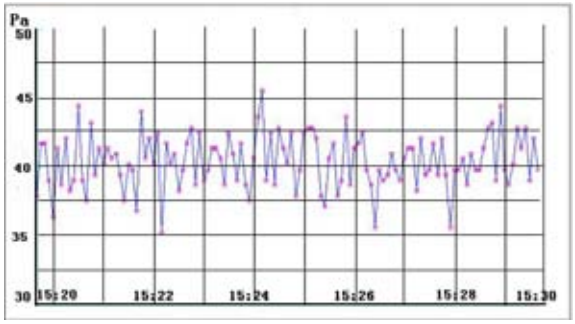

Fig 7 system terminal static pressure inspecting picture

The VAV control system is not only fixing the terminal device and gearshift air fan, but also has the total control system that is made up of some controlling loops. The VAV control

system's running condition will be changed following the time varies, which could assure the system's basic demand depending on the Automation Control such as the comfortable room temperature, the sufficient fresh air, the benign airflow and the normal indoor pressure and so on.

The chiller unit's VAV control includes the loops of ventilator control, back-flow fan control, fresh airflow control and so on. We can see that both the VAV air-conditioning system and the control system are combined tightly and indiscerptiblely. The main task of the control system is that it could adjust the supply airflow automatically and adapting the variable room load, which can achieve the requests of different function room's different temperature parameters and adjust the ventilator's the rotate speed so that it could reduce the running energy consumption in the air-conditioning system.

CONCLUSION

The automation control of the VAV air-conditioning system in the engineering practice mostly adopts the static pressure control scheme. However, it often exists the problem that super-cooling and super-heating of local district in the Building, the insufficient fresh airflow that dreggy air in the air-conditioning room. From the theoretical analysis, the control tactics principles of the cooling on demand and TRAV have the characteristics of energy-saving and stability, the system demands the fan power is less than the static pressure control system, when the flow drops by the fixed flow's 50%, the request fan power has been fallen below 15% of the fixed power according to this algorithm.

The task has already carried out the software testing and physical system's primary debugging in Building Environment and Intelligence Laboratory of Beijing Union University, testified its feasibility. It can be seen that the control principle and the algorithm have higher reference values. At the same time, it has the practical and immediate significance to improving the running efficiency and reducing energy consumption according to the VAV air-conditioning system's all-around energy-saving and optimal running.

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