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Design and Implementation of Heating Saving Energy System based on CANBus

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Abstract

Heating saving energy plays a very significant role in the energy saving industry. CANbus is a modern system in reliability improvement design concept which shows the transmission distance is longer than ordinary methods, and it can hang node on the optional position in availability distance. The nodes are linked in parallel, and not interfere with each other. By using the CANbus technology, the relay output module with a radiator, thermocouple acquisition module is linkedto the temperature sensor. The temperature sensor collects information from the outside system. Relay output module controls heating valve based on the temperature information, and make temperature of the room controlled automatically. Four energy-saving modes are developed in this project. Testing result reflects that the system designed under the new methodology offers outstanding results in energy-saving.

Keywords: *CANbus technology; heating saving energy; room control; automatic control*

1. Introduction

Maintaining indoor thermal comfort consumes about 50% energy [1], and most people spend about 90% time indoor [2], so building energy saving play an important role in formulating sustainable development strategies [3]. The North area is cold during the winter in china, and people usually adopt centralized heating. This method consumes great energy, and pollutes air and environment because of burning a lot of coal.

In recent years, air pollution is on the rise, air quality is getting worse, city hazy days increase gradually, which influence human body health, transportation, electric power department. In the heavy air pollution area, sulfide can form acid rain. Acid rain influences the soil, agriculture and ecological system greatly. Through the analysis[4], air pollution is mainly caused by the discharge of pollutants.Combustion emissions are the primarypollutant source. In Europe, Poland is one of the biggest users of district heating, and coal is the mainly fuel [5].Space heating is the largest energy end use, consuming more than seven quintillion joules of site energy annually in the U.S [6].Therefore, the energy-saving and emission reduction is a matter of great urgency. Reducing the amount of coal combustion must be enforced.

People presented a lot of methods to decrease the emission of pollution, encourage energy efficiency. [7-11]Coal was substituted for other alternative fuels at first, such as gas boiler, oil boiler, biomass boiler or the mixed fuel boiler replaced coal boiler. The literature analyzed different emission, and how to make the fuel utilization rate is higher.

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Another thought was presented [12-14], heat pump was used for the energy saving. Heat pump is a device that can transfer heat from low to high heat source. The low heat source can use water, including sea water, waste water, ground water, surface water, and ground source heat pump, air source heat pump.

Wonjun Choi et al., proposed three types of models and analyzed the performance of multi-storey double skin façade. It was found that significant energy saving is possible if multi-storey DSF is integrated with an HVAC system as a preheating space [15].

H.İ. Tol et al., presented a method for the design of a low-energy district heating system [16], and proposed optimization method reduced significant heat loss from the network, and optimized pipe diameters, network layout.

All of the above literatures, regardless of which kind of technology used,thatsupplied necessary temperature in the room. But rooms may be unused.

Wang et al., used STC10L12XE micro-controller unit and LCD made in TOPWAY, digital temperature sensor, the clock chip made in Dallas company, designed heating energy-saving intelligent control system, designed 5 switches and 2 protective gear [17]. The system was applied to two teaching builds. The two buildings have the same size, the same orientation. Compared with the traditional method, energy saving is 2.558MWh every day.

Wang et al., designed heating energy saving system according to the formula Q= $cm\Delta t = c\rho V\Delta t$. The system added an electric control valve for each building, a field controller, 4 temperature sensors was installed in each building. The system could control the whole building [18].

Three layers network structure were adopted, i.e., the Internet, GPRS, ZigBee. A heating energy-saving monitoring system was constructed [19].The GPRS network connected the upper web service and the lower ZigBee. This system can collect the real-time temperature data, and process, store and upload. This system can capture the data information of every household heating.

Mu *et al.* designed a zone and time control system, added the time controller and electric control valve [20]. Different heating demand areas were monitored by the zone and time system. The system achieved automatic control. When the area needed the zone and time control, the system selected typical rooms, put the temperature sensor in these rooms. The system collected room temperature to control the electric valve. The system has achieved control to the different area.

STC10L08XE MCU, CC2430 chip and the DS18B20 temperature sensor were used as the core, designed the heating control system [21]. Indoor temperature sensors collected data, and sent the data to temperature control board through the RS-485 serial port, and then the data were processed by the corresponding program. At the same time, temperature controlled board communicated with a handheld terminalusing CC2430 chip.

Energy saving system was applied to control the whole building, when the heat demand is the same or similar, the system can play a very good effect. However, if the user's demand is different in the whole building, the system could not carry out the overall control[17-18], [20]. Information canbe collected for each user, but the cost is high [19]. The heating needs of different users were considered, but it used the RS-485 serial to realize the heating control system, there are many drawbacks [21]. In this paper, energy-saving heating system was designed using CAN technology, and different users' requirement was thought, and room control was achieved with a relatively low cost.

CANbus technology is Controller Area Network abbreviation, is the development of 80 years of the twentieth century, which can effectively support the distributed real time control bus serial communication network. The real-timeand the high reliability, are recognized by a large number of standards organization. CAN has become an open, free, standardization,

standardization protocol, it has been widely used in automotive electronics, industrial control, building automation and other fields, and even aircraft has applied the CANbus technology [22-23].

The heating energy saving system was designs based on CANbus technology in this paper. The aim is to reduce the amount of coal combustion. K-7110, K-8510, K-8511, K-8518 and temperature sensor were selected as the hardware equipment. Indoor temperature sensor gaged temperature. The data obtained upload to the control computer by the CANbus. According to the situation, the control computer sent command to the heating valve, opened or closed the valve to regulate the flow of hot water. The system has been applied to the heating energy saving control in a university, to save energy.

2. Theoretical Basis

The system was first applied to the university.On a university campus, the types of rooms are many and varied, such as the classroom, conference room, laboratory, et al. For an ordinary classroom, general using time is early morning 8:00 to afternoon 8:00, at night, these rooms are idle. For the meeting rooms and laboratories, the opening time is not fixed. These provided time basis for us to save energy.

In addition, the room temperature in the building has great inertia. When the heating is turned off, the indoor temperature decreases gradually, this refers to inertia. This inertia is directly related to the wall insulation, windows insulation, the effect of insulation is better, the temperature inertia is greater, the insulation time is longer. Accordingtothis property, the time for heating and decreasing heat flow is moved up. According to the experimental data of air conditioning in the building, the energy used for heating will be saved by 5% - 8% for every degree the indoor temperature decreases. On the contrary, the energy used for cooling will be saved by 15% - 20% for every degree the indoor temperature increases. Air conditioning is high efficiency equipment, if the coal fuel was used, more coal fuel will be savedbecause of the low using rate of coal. Therefore, before you leave, you reduce the heat flow, and the office will maintain the temperature at a low level, this can save more energy.

3. Hardware Design

The energy saving system used a computer to control all radiators in the whole building. This computer is the control center. The control center connectedwith CANbus, the CANbus connected control modules. The main control module is the thermocouple acquisition module and the relay output control module. The relay output module opened or closed the radiator, and the thermocouple acquisition module collected the temperature of the room. Between the control center and each remote node, communications use the master-slave mode, that is to say, the control center issues a command, and node completes the command.

The advantage of using theCANbus is the distance of communication transmission.The longest distance is 10 kilometers. Wiring diagram of the system is shown in Figure 1, all radiators were connected in a building by one bus.

Because the computer has nothe CANbus interface, the information is converted by the conversion module. K-7110 was selected and used for the conversion module. K-8510 and K-8511 was selected and used for thermocouple acquisition module, K-8518 was selected and used for relay output module. In figure 1, the two roomswere connected, and the connecting method of the other rooms is the same, thermocouple acquisition module connectedwith an outdoor temperature sensor in one room.The sensor was used for detecting the outdoor temperature.

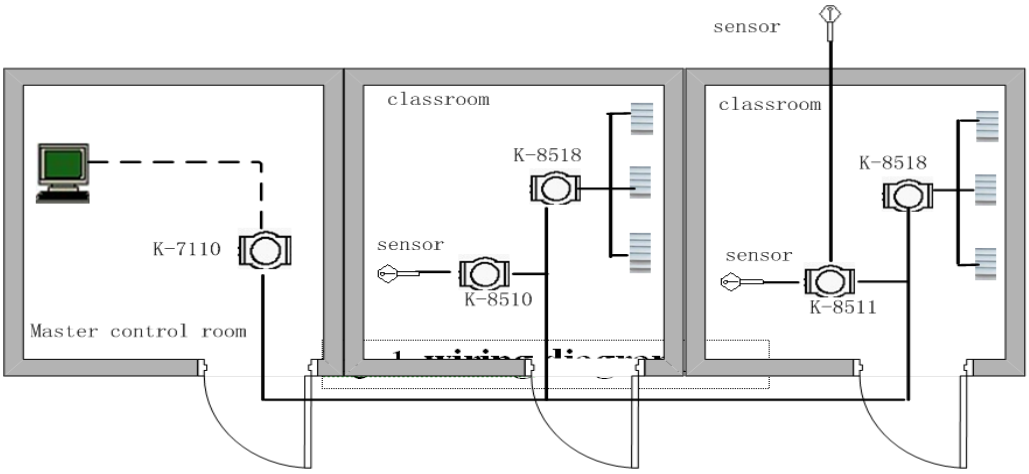

Figure 1. Wiring Diagram

3.1. K-7110

The RS232 of computer connects CAN network by K-7110, the role of K-7110 is conversion module. The data transfer rate is up to 400 frames per second, it supports CAN2.0A protocol and CAN2.0B protocol, the interface of bus is photoelectric isolation, the isolation voltage is greater than 1000V. Power supply voltage can be any values between 7V and 30VDC. Power consumption is 0.6W.

3.2. K-8510 and K-8511

K-8510 is a thermocouple acquisition module. It can collect remote 8 channel signals. K-8511 is the thermal resistance acquisition module, which can collect 6 channel thermal resistance signals, and converts them into the temperature value. That is to say, each channel can collect a room temperature, and communicates with the control computer by the serial port, and converts the data obtained to the temperature value. The control computer does not need to convert. Each room has one channel of acquisition module. 8 channels thermocouple acquisition module can connect eight rooms at most. The acquisition module is placed in the middle position. The collecting and transmission of signal is convenient.

K-8510 has a built-in receiver, controller and micro controller chip. Different manufacturers may use different types of chip. The baud rate of K-8510 and K-8511 is 20K, and it supports CAN2.0B protocol.

3.3. K-8518

K-8518 is a relay output module.It has 8 or 16 output channels. Relay contact capacity is 30VDC, 1A. It is matched with K-8510 or K-8511, and controls radiator to open or close. Each radiator takes one port of K-8518. In most cases, all radiators in a room take one K-8518, if the radiators are less in a room, a number of rooms can share a K-8518.The K-8518 was put at the appropriate location.

3.4. Control Valve

The wire diameter of the valve body is Φ 32mm.The material of the ball valve is PPR hot melt[24-26]. The hot melt plastic pipewas selected, because the hot water in pipe forms incrustation scale easily, which will influence the life of the valve switch. PPR hot-melt pipe will not scale, the scale is easy to form only in the spool, but because of the special requirements of the design, the incrustation scale does not affect the valve to open or close. In addition, temperature resistance of PPR plastic is between 75℃and 95 ℃, which meets the basic requirements of the hot water circulation in heating.

When the manual ball valve is using, its rotating torque is large, the motor power is large too, so the ball valve corewas transformed. The ball valve was reduced the rotation torque by reducing friction, without changing its structure. Because the valve core is not in sealing position, the scale does not influence it or a little. At the same time, O ring temperature resistance 140℃was used for solving rotating shaft seepage. The rubber ring elasticity is still intact after a long time of water soaking, and protects rotating shaft to be sealed for a long time. Because the valve core uses the steel material, and the surface is coated, the valve core surface is fouled rarely, even the foul, because the valve is used every day, the friction of the valve core surface and PPR will scrape the water scale timely.

The transmission part was designed. The rotating shaft put on a gear.Only 1/4 gear has been used. The gear diameter is 4 - 5 times larger than the diameter of motor gear, so the torque is large. Only 1/4 gear was used because the valve core can complete the switch to open or close only rotation 90°, which makes component compactly, and which can reduce the space volume of the whole equipment. The motor gear engages the teeth of the rotary gear, which turns the motor to the left or right,thus controls the valve to open or close.

The circuit automatically stop was designed, the motor automatically stops after the valve opens, and low current keep the state invariant, closes the valve after receiving a closing signal, and remains unchanged. Component of the electric valve has valve body, 12V DC slow motor, auto stop mechanism of commutation circuit, gear and other parts. Estimating the life of the valve body, PPR plastic is about 50 years.The other part runs the lowest 20000 frequency roughly, and considers high pressure and hot water environment again, so the life of the electric valve is very long.

3.5. Temperature Sensor

This system uses DS18B20 temperature sensor.The range of measuring temperature is between -55℃and +125 ℃. There is a temperature sensor in a room, which can completely meet the practical application.

4. Software Design

4.1. CAN Protocol

The communication between the modules of the system follows CAN2.0 protocol. It is a kind of field bus. It is a serial communication protocol, and it can effectively support the distributed real time control with a very high level of security. CAN iswidely used in many fields, such as the high-speed network, low cost multiplex wiring, and so on. The transfer rate of CAN is up to 1Mbit/s.

4.2. Initialization

The software includes the initialization module, control module, timing module, database module *et al*.

Initialization module: the station number and the channel number of 8510 are set up according to the wiring diagram.The station number and the channel number of 8511 are set up.The station number and channel number of 8518 are set up, and the energy saving module is initialized.

This system sets up the two temperature areas:

- Constant temperature interval: the temperature range is 18~22 ℃, when the room is in use, the temperature should be kept in this interval.
- Low temperature: the temperature range is 5~10 ℃, when the room is not used, the temperature should be maintained in this interval.

This system provides two warning cordons:

- The highest temperature warning cordon is 30℃.
- The lowest temperature warning cordon is 0℃.

4.3. Energy Saving Module

This system sets up four energy saving modules.

(1)Constant temperature module

This module always keeps the temperature in the range of 18~22℃. This model is applied to the room that is used for a long term. When the room temperature is too high, the system will close the valve, and when the temperature is too low, the system will open the valve. Because of the wall insulation, valves do not open or close frequently, which ensures the switch life.

(2)Schedule module

This model is applied to the room that is used in fixed time, such as most of the offices.These offices are used in the morning 8:00 to the afternoon 6:00.In order to saving more energy,evening can completely close the valve,.

(3)School timetable module

This model is applied to the classroom. The control computer opens the valve ahead according to the school timetable. When the classroom is no class, the control computer closes the valve. This can save more energy, and realizes intelligent control really.

(4)Manual module

This model is applied to those rooms that do not often use or do not need too high temperature, such as meeting room, laboratory. This valve can open a little. In this energy saving system, the valve opens about one fifth. A little hot water can pass through the heating, so the heating has a little heat but not high. When these rooms are used, the control computer can open the valve ahead. The model can save more energy.

The timing module: the system scans all the rooms at 20-minute interval. The control computer decides to open or close the valve according to the numerical time or temperature.

Database modules: in order to preventing the power off,this system needs to record each room mode into the database. After the system restarts, room temperature patterns are remained unchanged.

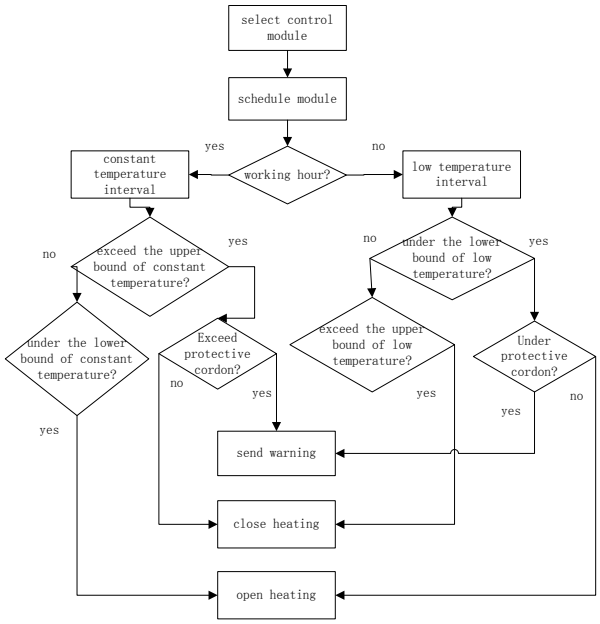

Figure 2.Flow Chart of Schedule Module

4.4. The Key Technology

The key point of this system is the temperature sensor collects the indoor temperature, uploads the data to the control computer.The control computer controls the switch to open or close according to the temperature.

Collect temperature:

(1). Firstly, setting the station number.
(2). Setting the channel number, every channel connects a room temperature sensor.
(3). Setting the function code, the temperature function code is H5
(4). Assembling query frame, the frame is designed to check the temperature
(5).Sending frames
(6).Receiving the return frame
(7).Splitting the frame, and analyze the received content, extract temperature.

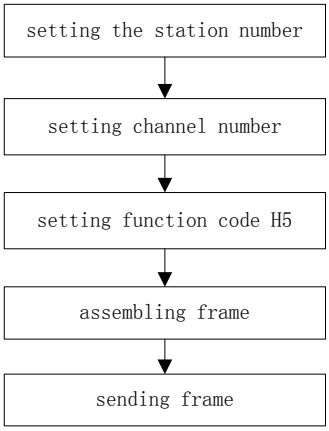

Figure 3.Collecting Temperature

Open the valve or close the valve:
(1).Setting the module station number.
(2). Setting the channel number, each channel connects a heating, all heating in a room may occupy multiple channel numbers, but in general all heatingin a room were connectedto a module.
(3). Setting the function code is H8.
(4). Setting the setout parameter.When the valve is opened,the proper port is set to 1.When the valve is closed, the proper port is set 0.
(5). Assembling the command frame.
(6). Sending the command, and open the heating valve.

5. Discussion

(1) This system uses the CANbus, because it has many characteristics.Its characteristics are suitable for the system [22], such as:

- Low cost
- Bus utilization rate is high, in theory, the number of nodes on the bus is not limited, but in practice, the number of nodes is 110, and this is enough to use.
- Data transmission distance is up to10km.
- The data transmission rate is up to 1Mbit/s.
- Parallel structure is adopted between nodes.When a node failures, it does not affect the normal work of other nodes.
- The CANbuscanwork for a long time.

Every node is a relatively independent module.This module can be connected in any location.Wiring is convenient. The CANbusis suitable for building energy control.

(2) The system provides different energy model for different users.

In a building, room typesare many and varied.The utility time of each room is not identical. The system provides multiple energy saving modes, avoids the defects of the single model. The system is flexible, and that will not affect everyone's needs, and it can save energy.

(3)Room control

The thermal pipeline is constructed from the top story, when the hot water flows, the highest point is hottest, and the lowest point is the coldest. When the building was built, although the number of radiators is short on the top story at the same area, the number of radiators is most on the ground floor, the heat balance and the fixed balance has greater error. The top room is hottest.Then gradually cooled until the bottom, or the middle floor also has the uneven problem.

At present, there are some similar systems, but they can control the whole building. That is to say, a temperature measuring device was installed in a building. They can control the whole building. Butthe system in this paper can control the heat flow of each room, in order to reducing loss from the source. That is to say, the system can control each room. The system can monitor the classified room according to the time.The different rooms operate according to the different mode. The system can save more energy.

Two rooms were selected in the engineering building of our university.Theirarea is almost, and location is near. The room number is 217 and 219. Schedule modulewas selected.The 217 room has not been controlled, and the 219 room was controlled by the energy saving system. Figure 4 showed data of heat meter and the inlet water temperature and return water temperature in the 219 room during the second half of November. Figure 5 showed data of

heat meter and the inlet water temperature and return water temperature in the 217 room during the second half of November.

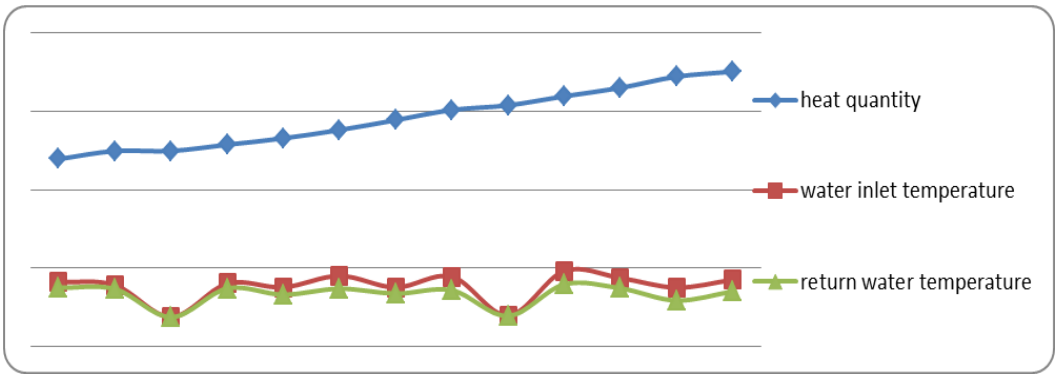

Figure 4.The Data of 219Room

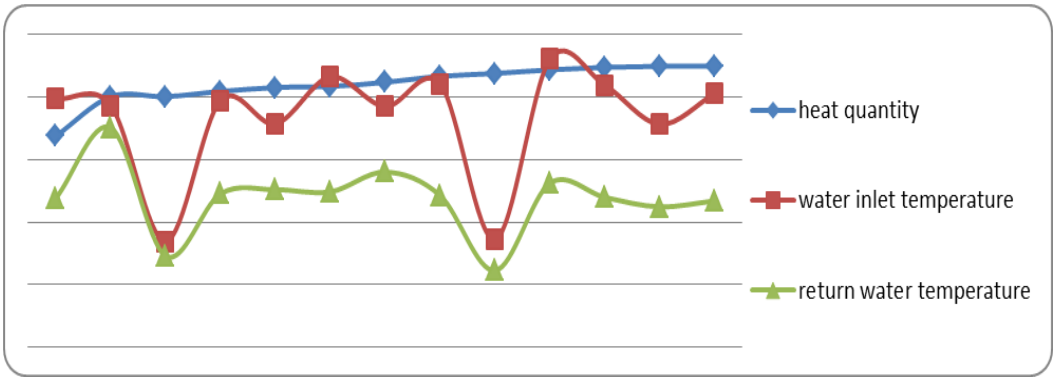

Figure 5. The Data of 217 Room

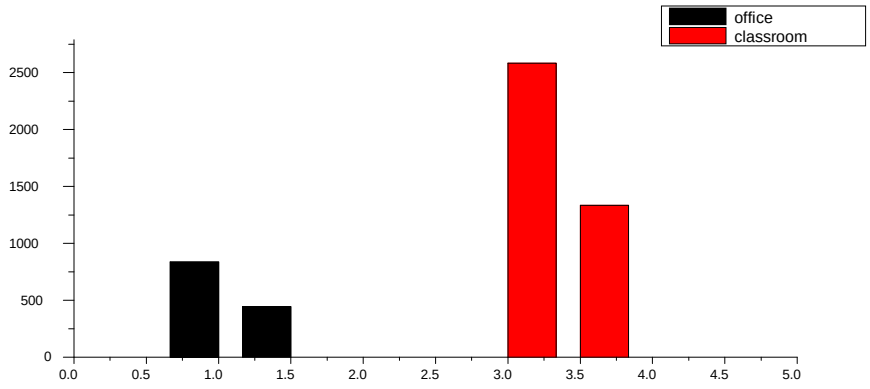

Figure 6. Heat Consumption Comparison of TwoOffices and Two Classrooms

Figure 6 is heat consumption comparison of two offices and two classrooms during six months. Two offices' area is about 28m^2, and location is near. Two classrooms' area is about

94m^2, and location is near.The one room was controlled by this system, and the other not in the two types of rooms.

$$E = \frac{\Delta hc_{R1} - (1+f)\Delta hc_{R2}}{\Delta hc_{R1}} \quad (1)$$

$$\Delta hc = hc_{day2} - hc_{day1} \quad (2)$$

E-- Fractional energy saving.

Δhc–It is heat consumption of a room in a period time.

f– the heat meter error.When flow is small,the temperature varies greatly between water inlet and return water, f is 5% [27].

Based on the above data, the following results were obtained: the office room saved energy about 44% during this time,and the classroom saved energy about 45%. The result exceeded the expected goal. This year, the winter is warmer, and temperature is higher than last year. This is a major cause. The heating valve was closed most days in the controlled room.

6. Conclusion

This paper presented a heating saving intelligent system using CANbus technology, and it is applied in the education school or office building. Coal boiler, gas boiler, oil boiler, biomass boiler, and heat pump et al can be used energy source. Rooms can be divided exhaustively in this system, and rooms were controlled according to the different use time.The radiator valve was closed when userwas absent, and pre-heating was going before user return. The system was able to distinguish the range of temperature according to user requirement. The system satisfied user requirement besides saving energy greatly.

References

[1] N. Enteria and K.Mizutani,“The role of the thermally activated desiccant cooling technologies in the issue of energy and environment”, Renew Sustain Energy Rev.,vol. 15, (**2011**), pp. 2095–122.
[2] R. Qi, L. Lu and H.Yang,“Investigation on air-conditioning load profile and energy consumption of desiccant cooling system for commercial buildings in Hong Kong. Energy Build, vol. 49, (**2012**), pp. 509–18.
[3] D. H. W. Li, L. Yang and J. C.Lam,“Zero energy buildings and sustainable development implications e a review”, Energy, (**2013**), vol. 54, pp. 1e10.
[4] A. Zanobetti, E. Austin, B. A. Coull, J. Schwartz and P. Koutrakis,“Health effects of multi-pollutant profiles”,Environment International, vol. 71, no. 13, (**2014**).
[5] K. Wojdyga, M. Chorzelski, E. Rozycka-Wronska,“Emission of pollutants in flue gases from Polish district heating sources”, vol. 75, no. 157, (**2014**).
[6] H.-W. Lin and T. Hong,“On variations of space-heating energy use in office buildings”,Applied Energy 111, vol. 515, (**2013**).
[7] B. Moghtaderi,“The safety implication of low heating rate pyrolysis of coal/biomass blends in pulverised fuel boilers”,Journal of Loss Prevention in the Process Industries, vol. 14, no. 161, (**2001**).
[8] M. Pronobis and W. Wojnar,“The impact of biomass co-combustion on the erosion of boiler convection surfaces”, Energy, Conversion and Management,vol. 74, no. 462, (**2013**).
[9] J.F. González-González, A. Alkassir, J. San José, J. González and A. Gómez-Landero,“Study of combustion process of biodiesel/gasoil mixture in a domestic heating boiler of 26.7 kW”, Biomass and Bioenergy, vol. 60, no. 178, (**2014**).
[10] C. D. Ray, L. Ma,T. Wilson,D. Wilson,L. McCreery and J. K. Wiedenbeck,“Biomass boiler conversion potential in the eastern United States”, Renewable energy, vol. 62, no. 439, (**2014**).
[11] R. Saidur, E.A. Abdelaziz, A. Demirbas, M. S. Hossain and S. Mekhilef,“A review on biomass as a fuel for boilers”,Renewable and Sustainable Energy Reviews, vol. 15, no. 2262, (**2011**).

[12] S.-H. Yang, S.-D. Lee, Y. J. Kim and J. Y. Rhee,"Greenhouse Heating and Cooling with a Heat Pump System using Surplus Air and Underground Water Thermal Energy", Engineering in Agriculture, Environment and Food, vol. 6, no. 86, (**2013**).
[13] J. Luo,J. Rohn,M. Bayer,A. Priess,L. Wilkmann andW. Xiang,"Heating and cooling performance analysis of a ground source heat pump system in Southern Germany",Geothermics, vol. 53, no. 57, (**2015**).
[14] M.R. Errera, S. Lorente and A. Bejan,"Assemblies of heat pumps served by a single underground heatExchanger", International Journal of Heat and Mass Transfer, vol. 75, no. 327, (**2014**).
[15] W. Choi, J. Joe, Y. Kwak and J.-H. Huh,"Operation and control strategies for multi-storey double skin facades during the heating season",Energy and Buildings, vol. 49, no. 454, (**2012**).
[16] H. İ. Tol and S. Svendsen,"Improving the dimensioning of piping networks and network layouts in low-energy district heating systems connected to low-energy buildings: A case study in Roskilde, Denmark", Energy, vol. 38, no. 276, (**2012**).
[17] Z. Wang, B. Zhang andW. Hua, "Design of the Intelligent Temperature Control for Building Systems", process automation instrumentation, vol. 33,no. 59, (**2012**).
[18] X. Wang, X. Guo and L. Zhang, "Development of energy saving control system for heating system in universities", journal of HV&AC, vol.42, no. 113, (**2012**).
[19] S. Zhang, Q. Lang andT. Xiao,"Design of Wireless Remote Coordinator for Heating Energy Conservation Monitor System",Computer Measurement & Control, vol. 20,no. 1251, (**2012**).
[20] L. Mu, C. Zhang, B. Wang, D. Zhang and T. Zhang,"Energy saving measurement and analysis of zone and time control system for heating systems",journal of HV&AC, vol. 43, no. 109, (**2013**).
[21] H. Chen, A. Wang, J. Luo andX. Wang,"Design and Implementation of the Heating Control System Based on CC2430 Chip and MCU",process automation instrumentation, vol. 33, no. 17, (**2012**).
[22] G. Craessaerts, K. Maertens and J. De Baerdemaeker,"A Windows-based design environment for combine automation via CANbus",Computers and Electronics in Agriculture, vol. 49, no. 233, (**2005**).
[23] H.A. Thompson, H. Benitez-Perez, D. Lee, D.N. Ramos-Hernandez, P. J. Fleming and C.G. Legge,"A CANbus-based safety-critical distributed aeroengine control systems architecture demonstrator", Microprocessors and Microsystems, vol. 23, no. 345, (**1999**).
[24] B.-C. Ahn and J.-Y. Song,"Control characteristics and heating performance analysis of automatic thermostatic valves for radiant slab heating system in residential apartments",Energy, vol. 35, no. 1615, (**2010**).
[25] P. Weker and J.M. Mineur,"A performance index for thermostatic radiator valves",Applied Energy, vol. 6, no. 203, (**1980**).
[26] D. Ndiaye and M. Bernier,"Modelling the bleed port of a thermostatic expansion valve,"International Journal of Refrigeration, vol. 32, no. 826, (**2009**).
[27] H. Di, Z. Wang and Y. Xiao, "Maximum permissible error of heat meter in operation",Journal of HV&AC. vol. 32, no. 113, (**2002**).

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