Construction of Intelligent Environmental Control Laboratory for Renewable Energy

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Abstract: Based on the residents' demand for central air-conditioning systems in cold winter and hot summer areas, an air-source heat pump central air-conditioning system was built, and a renewable energy intelligent environmental control laboratory was built to explore the comfort and energy saving of the system. At the same time, it enriches the innovative experiment content of undergraduates majoring in the building environment and energy application, and provides a scientific research platform for graduate students, teachers, and the society.

1 INTRODUCTION

In the teaching of science and engineering in colleges and universities, experimental teaching plays a vital role. University engineering laboratories are an important platform for cultivating engineering students' innovative spirit and innovative ability. Strengthening the construction of engineering laboratories will help deepen innovation and entrepreneurship education development (Ge, *et al.* 2021). However, most of the school's professional laboratories have outdated equipment due to tight funding, and have not kept up with the pace of industry development, which has seriously affected the quality of talent training. The college is centered on the cultivation of students' ability, facing social needs (Zhang, *et al.* 2020), and Wuhan Comfort Yibai Technology Co., Ltd. (referred to as "Comfort 100") to jointly build a renewable energy intelligent environmental control laboratory.

2 LABORATORY CONSTRUCTION PLAN

2.1 Air Source Heat Pump Central Air Conditioning System

How to achieve environmental comfort and energy saving is the focus of research on household central air conditioners. Renewable energy comes from nature and is inexhaustible. The natural environment such as air contains a large amount of low-grade heat energy that cannot be directly used. After the energy level is raised by a heat pump, it can be used as a cold and heat source for air conditioning to form a renewable energy utilization system (Ye 2017). Air source heat pumps use renewable energy to transfer the energy of outdoor air from a low-level heat source to a high-level heat source. The evaporator absorbs heat for cooling, and the condenser releases heat for heat transfer. The air source heat pump unit has the characteristics of energy saving, dual use of cold and heat sources, no need for cooling systems and boilers, and is particularly suitable for the hot summer and cold winter areas in my country as the cold and heat source of the centralized air conditioning system (Lu 2008a). Compared with other heating equipment, air source heat pumps have more obvious advantages in energy saving and environmental protection. This system uses air source heat pump cold and hot water

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units as the cold and heat source equipment, and uses fan coils, radiant floors, and radiators as the cooling and heating terminals of the system respectively, which facilitates the comparison of the heat effect and human comfort of the terminal equipment in the later period. The schematic diagram of the intelligent floor heating and air-conditioning integrated machine is shown in Figure 1.

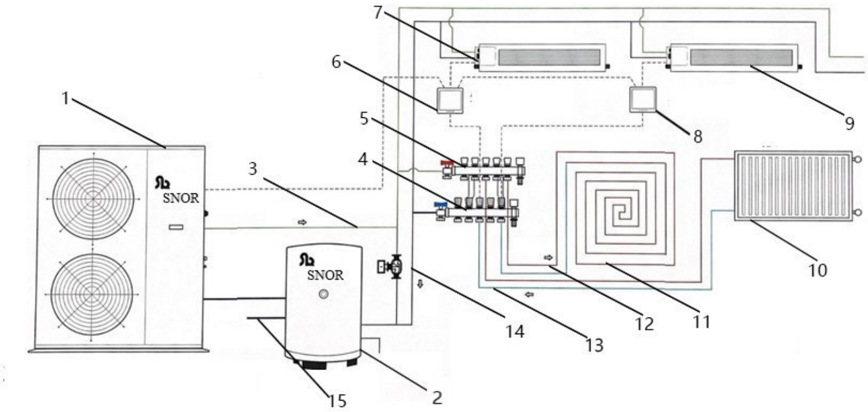

Figure 1: Schematic diagram of the intelligent floor heating and air-conditioning integrated machine system.

1-Variable-frequency air source heat pump unit 2-Buffer tank 3-Outlet pipe 4-Water trap 5-Water separator 6,8-Intelligent temperature controller 7,9-Fan coil 10-Radiator 11-Floor heating 12-Hot water outlet pipe 13-Cold water return pipe 14-Return pipe 15-Water supply pipe

In order to ensure indoor air quality, a fresh air system is required. In addition, the humidity in Wuhan is relatively high, especially during the rainy season, requiring a dehumidification system. Therefore, the central air-conditioning system includes five parts: fan-coil system, floor heating system, radiator heating system, fresh air system, and dehumidification system, which are introduced in the following.

2.1.1 Fan Coil System

The laboratory is located on the first floor of the teaching building (a total of five floors). The south faces the sun and has windows, the east and north are aisles, and the west is adjacent to another laboratory. There is no air conditioning system around, and the area is 12*7.9=94.8m^2. According to *Air Conditioning Design Manual* estimates, the outdoor unit uses SNOR inverter air-cooled heat pump unit SHDA18.

In order to analyze and compare the actual operating performance and noise of different fan coil units in the later period, three fan coil units from different manufacturers are selected for the indoor unit (in order to keep the fan coil manufacturer secret, the manufacturer name is replaced by "*", and the following Same thing). The fan coil configuration of the indoor unit is shown in Table 1.

In order to make reasonable use of the laboratory space and facilitate teaching, the fan coil is exposed horizontally, hung on the upper part of the room, with its own air inlet and outlet.

Table 1: Indoor unit fan coil configuration table.

Serial number	area	Unit cooling load	Correction factor	Total cooling load	Indoor unit		quantity	Indoor unit cooling capacity	Total cooling capacity	Actual cooling load
	m^2	W/m^2		W	Product name	model	tower	W	W	W/m^2
1	94.8	220	1	20856	Shi Nuo fan coil	FCSD07L	1	5600	5600	213
2					**fan coil	FCAA12L	1	11250	11250	
3					**fan coil	HFCF04	1	3300	3300	
total				20856			3		20150	

2.1.2 Floor Heating System

The floor heating system has been widely adopted by the construction industry in recent years due to its advantages of comfort, sanitation, energy saving, and good thermal stability. The industry has conducted extensive research on it: Hongwei Tang and Xiaoli Sun (2019) studied the application of terminal design, Yunxia Zhu (2018) analyzed the key points of floor heating design, Zhiyong Lei (2016), Yue Wu *et al.* (2016) analyzed its energy-saving effects and heat transfer, etc. However, how to better save energy under the condition of meeting comfort needs to be further explored. In order to find a more energy-efficient floor heating mode, this system adopts four methods of laying: wet (wood floor, stone) and dry (wood floor, stone). The pipe spacing of wet floor heating is 50mm, and the bottom plate uses wooden floor and floor tiles; the pipe spacing of dry floor heating is 150mm, and the bottom plate uses wooden floor and floor tiles.

2.1.3 Radiator Heating System

The radiator heating system is an abbreviation of a system that heats the end with a radiator. The heat is mainly transferred to the indoor space quickly by means of hot air convection and radiation, so that the indoor reaches the ideal heating temperature at the fastest speed, and the time required is about one-fifth of the floor heating.

Estimate the total heat load based on the laboratory area and the standards of the Air Conditioning Design Manual, and then select the indoor unit-the radiator model based on the total heat load. In order to compare the actual operating performance of radiators from different manufacturers in the later stage, radiators from three manufacturers were selected. The specific configuration is shown in Table 2.

Table 2: Radiator heating equipment configuration table.

Serial number	area	Specific heat load	Total load	Indoor unit		quantity	Radiator heat	Total calories	Actual heat load
	m2	W/m2	W	Product name	model	tower	w	W	W/m2
1	94.8	130	12324	***	22PKKP600*2200	1	3985	3985	116
2				***	22PKKP600*2000	1	3622	3622	
3				***	22PKKP600*2000	1	3417	3417	
total			12324			3		11024	

2.1.4 Fresh Air System

In the hot summer or cold winter, people expect to be in an air-conditioned room, which will cause various air-conditioning diseases. The main cause of these diseases is the poor indoor air quality. In order to solve the problem of indoor air quality, opening windows for ventilation is the most convenient and effective way to improve indoor air quality, but this will cause a great waste of energy and affect indoor cooling and heating effects. If the central air-conditioning and fresh air system are used at the same time, the two complement each other and complement each other, which can not only ensure the appropriate indoor temperature, but also ensure the fresh indoor air. Therefore, it is necessary to introduce a fresh air system into the central air-conditioning system.

The model of the fresh air blower is determined according to the amount of fresh air required in the room. Calculate the required fresh air volume Q in the building, considering both the "indoor number of people" and "indoor ventilation frequency", in order to ensure the indoor air quality, the mechanical ventilation host is selected with a larger value (Yu and Xiong 2017). According to *Design Standard for Energy Efficiency of Public Buildings (GB50189-2019) 3.0.2* and *Code for Design of Heating, Ventilation and Air Conditioning of Civil Buildings (GB50736-2016) 3.0.6*, the required fresh air volume $Q \geq 240m^3/h$.

When the fresh air system is installed separately and the air exchange rate is large, the fresh air will have a greater impact on the heating load and air conditioning cooling load. In order to save energy, a full heat exchange fresh air blower is used, and the exhaust air is used for pre-cooling and fresh air preheating to reduce the fresh air load (Gu, *et al.* 2019). As shown in Figures 2 and 3.

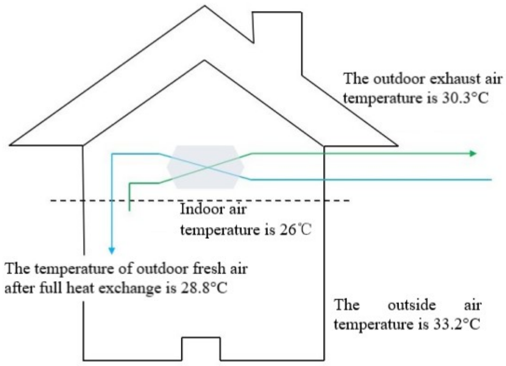

Figure 2: Schematic diagram of total heat exchange in summer.

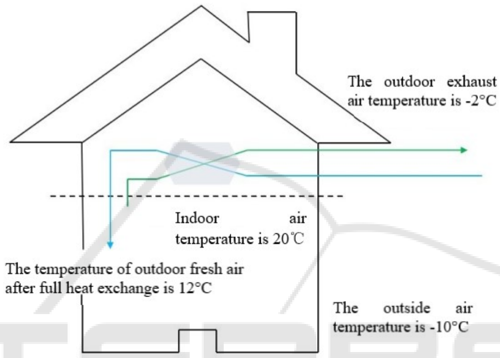

Figure 3: Schematic diagram of total heat exchange in winter.

At the same time, the outdoor air quality is sometimes poor, especially in autumn and winter for a long time. When considering the delivery of outdoor air indoors, the quality of the input outdoor air must also be considered. The selected fresh air system must have the function of preventing haze. It can effectively remove PM2.5, bacteria, peculiar smell, etc., to ensure the freshness of the indoor air. In order to meet the above requirements, this system uses SNOR's SFD250-EM anti-haze full heat exchange fresh air blower, and its configuration is shown in Table 3. In order to save energy, fresh air operation can be realized during the transition season (Gu, *et al.* 2019, Liu, *et al.* 2020).

Table 3: Fresh air system configuration table.

Area	Storey height	Volume	Number of air changes	Ventilation volume	New fan model	Quantity	Remarks
m2	m	m3	Times/hour	m3		tower	
94.8	3.8	360.2	0.6	216.1	SFD250-EM	1	250m3/h

2.1.5 Dehumidification System

Conventional air-conditioning systems generally use heat and humidity coupling control methods in summer to cool and dehumidify the air, and at the same time remove the sensible heat load and latent heat load in the building. After the condensation and dehumidification treatment, although the moisture content of the air can meet the requirements, the temperature is too low. Sometimes in order to meet the requirements of the supply air temperature, it needs to be reheated (Wang 2019). In addition, the indoor temperature is suitable in some seasons, but the air humidity is relatively high, especially in the rainy season. In order to avoid energy waste, an independent temperature and humidity control system is used to control the indoor temperature and humidity separately (Lu 2008b). According to actual needs, run a fresh air system or a full dehumidification system.

The model of the dehumidifier is determined according to the amount of dehumidification required for the indoor space of the building: the comfortable humidity of the human body is 40-60%. The amount of water that needs to be removed in a day from 90RH% to 60RH% is calculated to determine the model of the dehumidifier. The dehumidification system uses SDAT58/500 central dehumidifier from SNOR. The nominal dehumidification capacity is 58L/day, the air exchange rate is 500m3/h, and the heat recovery rate is 65-85%.

2.2 Environmental Intelligent Control System

With the development of wireless networks, the level of automation control of the central air-conditioning system is gradually improving, and the requirements for residential comfort are also increasing. The system adopts SNOR intelligent control panel/SNOR intelligent IOT template + SNOR intelligent energy management to form the SNOR IOT environmental intelligent control system, and realizes precise temperature control of 0.5℃ through a small program, and the operation mode of the remote control system. The equipment operating data is collected through the remote electronic control system to monitor and manage energy consumption (Yang and Han 2020). It is also possible to connect to the remote control system of the system through the mobile phone APP-Comfort Smart Home to monitor the operating status and operating parameters of the system.

The selected SNOR CBK10 thermostat can perform big data analysis on temperature and humidity according to seasonal weather changes and different scene usage habits, and customize personalized solutions and intelligent control equipment for users to integrate people with the building, create a beautiful feeling of being close to nature and comfortable.

3 EXPERIMENTAL CONTENT AND TEST EQUIPMENT

In order to enable students of this major to fully grasp the central air-conditioning system and highlight the characteristics of the building environment and energy application majors, the system can be used as a scientific and technological innovation platform for undergraduates, and the following experiments are set up:

(1) Test the thermal efficiency of the fresh air ventilator.

(2) Test the dehumidification effect during the rainy season.

(3) Test the air distribution of the fan coil.

(4) Test the distribution of the temperature field in the radiant floor heating room.

(5) Test the temperature and humidity of floor heating, simulate the temperature field and humidity field respectively, and find the most energy-saving and comfortable floor heating mode.

(6) Study the energy-saving effect of dual-supply (fan coil + radiant floor heating) of household air source heat pump units.

(7) Study the distribution of indoor air distribution at different heating terminals.

(8) Study the comfort of the human body in different heating terminals.

The testing instruments currently available are: JTDL-80 temperature and heat flow dynamic data acquisition system, ultrasonic flowmeter, enhanced environmental tester, WSZY-1 temperature and humidity automatic recording instrument, infrared thermometer, carbon dioxide tester, PM2.5 Tester, air particle counter, indoor air quality detector, digital clamp multimeter, etc.

The combination of experiment and actual engineering can not only stimulate students' interest in experiments and mobilize students' enthusiasm, but also enable students to grasp the frontier research trends of the industry, improve students' scientific research literacy, and cultivate more talents for the development of the industry. At the same time, it also enriches the experimental teaching content of undergraduates and improves the traditional experimental teaching mode.

The system can be used not only as a scientific and technological innovation platform for undergraduates, but also as a scientific research platform for graduate students and teachers to realize basic research on the application of renewable energy, so as to better study the comfort and energy saving of the air source heat pump central air conditioning system; At the same time, it is open to the society and serves as a training base for enterprises to explore the best mode of air source heat pump central air-conditioning system for comfort and energy saving together with people in the same industry.

4 CONCLUDING REMARKS

In short, laboratory construction is extremely important. The air-source heat pump central air-conditioning system and the environmental intelligent control system are the basis for the construction of the laboratory. To do well in the testing and research work of this experimental platform, researchers need to have high standards and strict requirements, testing instruments should be as advanced and high-precision as possible, and the experimental content also needs to be further expanded and deepened. In this way, we can provide high-quality experimental teaching and scientific research platforms for teachers, students and the society.

At the same time, the school makes full use of social resources, gives full play to their respective advantages, initiates school-enterprise cooperation, and jointly builds an experimental platform, realizing a new mode of industry-university-research school-enterprise cooperation with resource sharing, complementary advantages, and a win-win situation. This will not only improve the school's experimental teaching and scientific research conditions, and organically combine teaching, scientific research and practice, but also contribute to the development of the industry and the energy conservation and environmental protection of the society.

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