ENERGY SAVING SYSTEM FOR BUILDING COOLING AND HEATING INTEGRATION BASED ON BUILDING INFORMATION MODELLING TECHNOLOGY

by

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In order to understand the energy-saving system of building cooling and heating integration, the author proposes a research on an energy-saving system of building cooling and heating integration based on building information modelling (BIM) technology. The author first analyzed the energy-saving performance of the system by establishing models for each module based on meteorological data simulated on the DeST software platform. Secondly, in order to analyze the energy consumption of the integrated system, it is necessary to establish a residential building model, and select the building model in the cold winter and hot summer areas of a city for analysis. The results show that due to the system's heat storage function, there is no need to consume electricity in spring and autumn. Compared to the electric heating hot water mode, the integrated system can save 1198.85 kWh of electricity in non-cooling and heating seasons, with a 100% energy-saving rate. Compared to not using an integrated system, it can achieve an energy-saving rate of 81.9% throughout the entire refrigeration and heating season, with significant energy-saving effects. The integrated heating, cooling and hot water system of BIM technology adopts the technology of cool storage and heat storage coupled with solar energy and heat pump technology. The system has simple structure, obvious energy-saving effect, good environmental protection, and can adapt to various climates throughout the year. The introduction of underfloor heating also increases the comfort of buildings and residences.

Key words*: BIM technology, integration, heating and heating*

Introduction

At present, people's requirements for the construction industry are becoming increasingly high, and the construction industry is constantly developing new technologies to reduce energy consumption in HVAC. As a building information modelling technology, BIM technology plays an important role in the installation and construction of HVAC. With the gradual enhancement of people's environmental awareness, people are also paying more attention the issue of energy consumption in HVAC. Therefore, relevant construction personnel actively apply BIM technology to reduce energy consumption, improve construction level, and increase economic and social benefits in the installation process of HVAC. The BIM technology is a kind of building information modelling technology. The BIM technology has been applied in various fields such as engineering design, construction, and engineering management, which plays an important role in reducing construction costs and improving engineering efficiency. At

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the same time, BIM technology has more obvious advantages than CAD drawing technology and modelling technology, so it has been widely applied in the construction field. The BIM technology has obvious characteristics of information integration. In the process of design and information collection, information models provide great convenience for information integration. From the perspective of building information modelling, this model enables designers of all processes to participate in the design process, and strengthens the connection between all processes, this provides a guarantee for the integration of the engineering design process [1].

The application of BIM technology in the process of HVAC design can use data carriers to construct corresponding information management platforms, which can directly improve the scientific rationality of HVAC design schemes. The main advantages of applying BIM technology in the process of HVAC design are: First, BIM technology can directly show the specific situation of HVAC design, and complete the transformation and construction of BIM 3-D data models by inputting HVAC system parameters and performance, thus creating a good and real effect. Accordingly, the accuracy and efficiency of 3-D rendering can be fundamentally realized, present the final results of the HVAC design plan. Secondly, it is mainly aimed at the database where BIM technology is located, which can be more accurate in the calculation of engineering quantities. The accuracy of HVAC calculation is also very significant, which is the ultimate goal of applying equipment parameters to effectively improve the quality of use in HVAC design. In addition, the characteristics of BIM are mainly reflected in its simulation and visibility, which can directly simulate the entire process of HVAC construction. By using 3-D visualization functions and practical dimensions to truly simulate the HVAC construction process, problems in the design and usage stages can be identified in a timely manner, and corresponding solutions can be optimized one by one, thereby directly reducing the cost of engineering solutions. This has increased the quality and efficiency of engineering and promoted the quality of HVAC design projects [2].

Literature review

In the stage of HVAC design, the first step is to implement corresponding differentiation for the overall building model. After division, necessary heat source locations should be set, and then the most suitable construction plan should be selected based on the corresponding locations. In the construction process, when dividing the corresponding areas, they should be based on the actual situation of the area. The differences in HVAC design among different areas are also significant. For example, office buildings mainly rely on seasonal changes to implement various heat or cold sources for supply. In the design process for HVAC terrorism, the main basis for implementing power consumption design is the scope and area of the construction project area. Generally, the larger the area, the larger the corresponding range. Nowadays, in the process of specific applications, using corresponding simulation software to apply BIM technology can calculate specific power consumption, and then establish necessary unit equipment based on the corresponding area size and regional cold source, and achieve the ultimate goal of control compliance. Domestic hot water is produced by electric heating or heating with natural gas or coal gas. This decentralized refrigeration and heating method for hot water production has low energy utilization efficiency and poor environmental friendliness. If coupled with three modules of refrigeration, heating, and hot water production, an integrated system is developed to achieve complementary energy utilization methods, which will greatly achieve the effect of energy conservation and emission reduction. Li *et al.* [3] applied BIM technology in the design of construction engineering projects, which can effectively play a good co-ordinating role in various practical work, effectively use all information involved in construction engineering projects, promote the improvement of the overall design effect of construction engineering projects, and avoid all kinds of contradictions. Yu [4] believe that BIM technology can be well applied in engineering projects and can simulate heat conduction, emergency evacuation*, etc.*, thus promoting the continuous improvement of construction efficiency and construction quality.

At present, there is already an integrated air conditioning and hot water system in the foreign market. But these systems are limited to using air conditioning waste heat to heat water. During this process, the cooling coefficient COP of the air conditioning system will decrease, which will affect the energy-saving effect and cannot be used in winter. Therefore, it has not been widely promoted. In order to better adapt to various seasons, while also considering the comfort of refrigeration and heating, and to use new energy to a greater extent, the author proposes a new integrated system that uses cold and heat storage technology coupled with solar energy and heat pumps. Solar energy is cost-effective, clean and environmentally friendly. By storing cold and heat, energy can be reasonably distributed, and the use of heat pump systems improves energy utilization efficiency. In addition, the Underfloor heating is used for heating in winter, which increases the comfort of the residence due to its uniform radiation [5, 6].

Methods

Integrated heating, cooling and hot water system designed by BIM technology

The principle of the BIM technology integrated heating, cooling, and hot water system designed by the author is shown in fig. 1. The entire integrated system is centered on an electrically driven chiller and incorporates a solar collector module to produce hot water. The heat collected by the entire system is concentrated in the heat storage tank, and the cold produced is concentrated in the cold storage tank for centralized distribution. Refrigeration uses fan coil units, while heating uses geothermal radiation heating. It consists of a water tank, an air-cooled cooling tower, a refrigeration fan coil, a pump, and a three-way valve. The hot water system consists of a solar collector and a heat storage tank. The geothermal heating system consists of a chiller unit, a heat storage tank, a cooling tower, a geothermal coil system, a pump, and a three-way valve. In summer, the three-way valve can be adjusted to form a cycle among the cooling tower, chiller, and storage tank, cooling the water in the storage tank to around 7 °C for

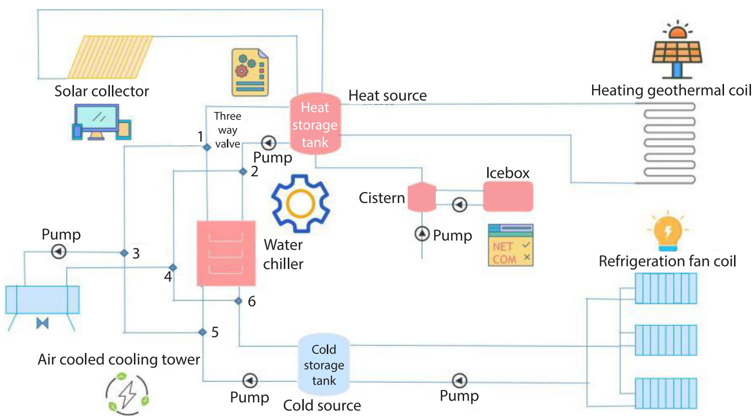

Figure 1. Schematic diagram of BIM technology building refrigeration, heating and heating integrated system

storage. This process can be carried out at the lowest temperature every day, which is beneficial for improving the cooling coefficient COP of the air conditioning system and saving electricity. When refrigeration is needed, the cold water in the cold storage tank can be introduced into the fan coil for circulating refrigeration. Due to the use of a cold storage water tank, the chiller can run for a period of time and then shut down for a while, achieving continuous cooling through the cold storage water tank. As a result, the chiller operates for less than the refrigeration cycle time, which can extend the lifespan of the chiller.

In summer, the solar radiation is strong, which can generally meet the demand for domestic hot water. The heat collected by the solar collector can heat the water heating in the heat storage tank to more than 70 °C, which can meet the demand for domestic water. When there is insufficient solar radiation on a certain day in summer and the water temperature cannot meet the requirements, adjust the three-way valve and use the condensation heat of the refrigeration system to heat the heat storage tank to the required temperature. In winter, the air conditioning cooling system is not used. However, solar radiation generally cannot meet the demand for indoor heating in winter. According to the design standards, the winter ground heating water temperature can be set at 55 °C. Adjust the three-way valve to allow the chiller and cooling tower to absorb heat from the outside and heat the water in the heat storage tank together with the solar collector to 55 °C for storage in the heat storage tank. When heating is needed, it is connected to the coil of underfloor heating and used for indoor heating through underfloor heating radiation. The heat pump can heat the water at the highest temperature in winter, which will improve the COP of the heat pump. Similarly, due to the heat storage tank being able to store heat, the chiller can operate intermittently, extending the service life of the unit. Winter domestic hot water can be extracted from the heat storage tank at 55 °C and then heated by a heat pump water heater to the required temperature above 75 °C.

Building model establishment

In order to analyze the energy consumption of integrated systems, it is necessary to establish a residential building model. Select a building model in a cold winter and hot summer area of a certain city for analysis. The entire building area is 190 m^2. The heat transfer coefficient of the residential model can be calculated or taken according to the national standards. The parameters of the building model are listed in tab. 1.

Table 1. Building model parameters

Name	Area	Number	Naterial	Heat transfer coefficient
Roof	172	1	Aerated concrete insulation roof	0.6
Floor	172	1	Concrete insulation floor	0.28
Window	1.5×1.9	8	Double layer metal frame glass window	3.3
Entrance door	2.6×4	2	Steel and wooden fireproof doors	3.1
Exterior wall	136.5	1	Concrete insulated exterior wall	1.03

Energy consumption model analysis

Based on the established building model, the heat load of the building can be calculated. Build models of various modules of the integrated system to calculate and analyze the energy consumption of the building model after using the integrated system.

Simulation of meteorological parameters

The simulation of meteorological parameters was carried out using the DeST software simulation platform. This platform was developed by the Environmental and Equipment Research Institute of the Department of Architectural Technology and Science at Tsinghua University. The DeST conducted in-depth research on the objective laws of the meteorological environment and established a meteorological model called Medpha, which simulates the generation of hourly meteorological data throughout the year using measured daily meteorological data. The basic data of Medpha comes from the measured daily data of 196 meteorological stations over the past 40 years since their establishment, including temperature, humidity, solar radiation, wind speed and direction, sunshine hours, and atmospheric pressure.

Calculation of building heat load

The heat load of the building model during the heating and cooling season is calculated by the heat consumption of the enclosure structure, and the heat load calculation formula:

$$Q = \sum KF(t_n - t_w)\alpha \tag{1}$$

where Q [W] is the thermal load, α – the amplification factor, mainly considering the heat release of indoor people, electrical appliances, sunlight, *etc*. The amplification factor can be selected as 0.98. The room temperature is set at 19 °C in winter, 26 °C in summer, and approximately equal to the daily average temperature in spring and autumn.

Solar collector heat collection model

According to the calculation method specified in the national standard *Technical Specification for Solar Heating Engineering*:

$$A_c = \frac{86450 Q_H F}{J_T \eta_{cl} (1 - \eta_L)} \tag{2}$$

Then the required solar area of the collector can be obtained.

Considering that solar collectors need to serve winter heating, the average heating load during winter is calculated. The names and values of various indicators in eq. (2) are listed in tab. 2.

Table 2. Calculation of collector area

Symbol	Name	Numerical value	Notes
Q_H	Heating load/W	4116.3	Count
F	Solar energy guarantee rate [%]	45	Value
J_T	Daily average solar irradiance [Jm^{-2}d^{-1}]	11.68	Retrieve
η_{cl}	Collector efficiency [%]	42	Value
η_L	Heat loss rate of pipe-line and water tank [%]	15	Value
A_c	Daylight area of collector [m^2]	34	Count

Energy consumption model of chillers

The calculation of the energy consumption model for chillers mainly considers the changes in the unit COP. For the convenience of modelling and calculation, the COP size of the unit under a series of outdoor temperatures is determined by using a pressure map, and an approximate formula is fitted accordingly. Select R134a as the working medium, set a fixed evaporation or condensation temperature, and the temperature at the other end depends on the outdoor temperature. According to the pressure chart, check a series of important values, use the theory of computation COP, and then multiply by each loss coefficient 0.56 to calculate the actual COP. Connect the COP obtained into a curve and use the outdoor temperature as the horizontal co-ordinate:

$$\varepsilon = \frac{q_c}{w_{\text{net}}} = \frac{h_1 - h_4}{h_2 - h_1} \tag{3}$$

where q_c is the cooling capacity and w_{net} is the net work of the compressor.

Refrigerator energy consumption model

The evaporation end temperature of the refrigerator is relatively constant, with a temperature of –26 °C selected. Due to the use of a water-cooled condenser to recover waste heat in the refrigerator, the COP of the refrigerator will also change due to changes in water temperature, similar to a chiller. The COP is calculated through a pressure plot and a fitting formula is developed. The selected working medium is R134a, with a loss coefficient of 0.56 for each item. After investigation, the daily refrigeration capacity of the refrigerator was selected as 0.878 kWh. So we can calculate the daily energy consumption and recyclable waste heat of the refrigerator.

Energy consumption calculation of integrated system

After research, it has been found that 100 L of domestic hot water can be used daily, and 210 L of winter heating hot water can be used. Based on the established energy consumption models for each part and the system operation mode, the energy consumption of the summer and winter systems can be calculated, as shown in figs. 2(a) and 2(b).

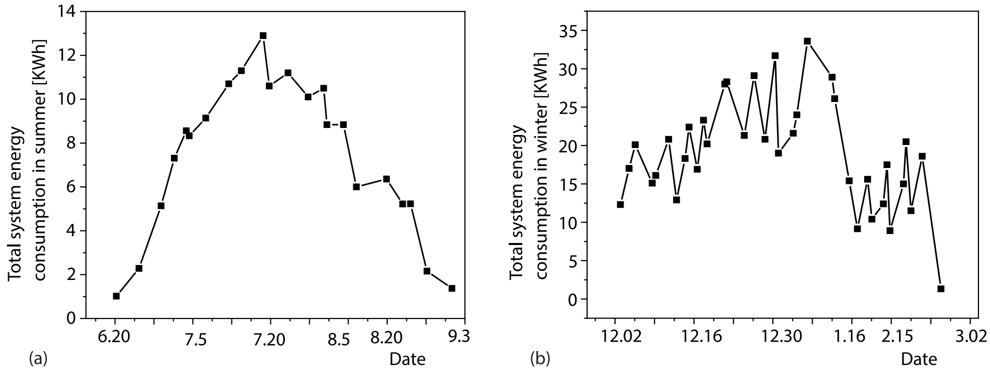

Figure 2. Total energy consumption of integrated system; (a) summer and (b) winter

After calculation, the total energy consumption in summer is 627.9 kWh. The total energy consumption in winter is 2714.5 kWh.

Energy saving analysis of the system

Analysis of solar energy conservation

The system can save a lot of energy due to the use of solar energy. According to statistics in winter, 3012.8 kWh of thermal energy can be collected. If these thermal energy is produced using an electric water heater (with an energy efficiency of 75%), it requires 4016.7 kWh of electrical energy. If a heat pump is used for heating, 602.5 kWh of electrical energy is required. In addition, the heat storage capacity of the system also allows for the complete realization of solar powered hot water production in summer without the need for auxiliary means.

Energy saving analysis of refrigerators

Due to the use of water-cooled condensation in the refrigerator, it can recover approximately 1.2 kWh of heat per day. In addition, after changing from air-cooled heat exchange to water-cooled heat exchange, the COP of the refrigerator has been improved, as shown in figs. 3(a) and 3(b).

It can be seen that in both winter and summer seasons, the refrigeration COP of the refrigerator is improved, thereby achieving energy-saving effects.

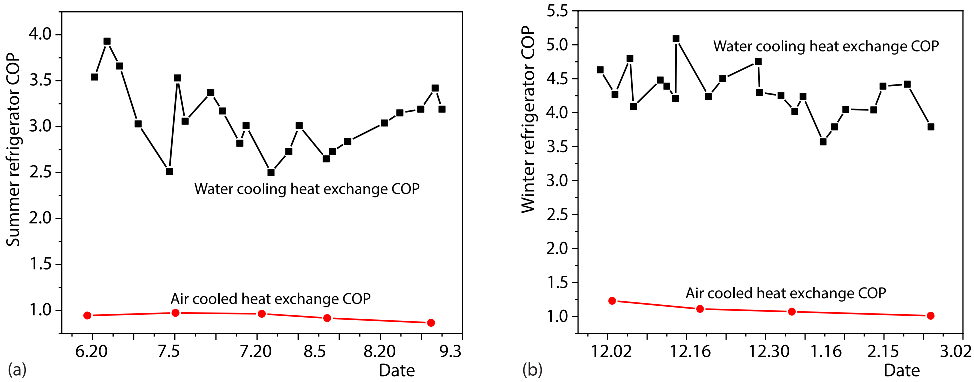

Figure 3. The COP of refrigerators with different heat exchange methods; (a) summer and (b) winter and summer

Energy saving analysis of system operation mode

The system cools during the lowest daily temperature in summer and heats up during the highest temperature in winter, which can improve the COP of the chiller.

The temperature of the cold and heat sources has a significant impact on the energy efficiency coefficient of the unit. For refrigeration unit, the theoretical energy efficiency coefficient formula of reverse Carnot cycle:

$$COP = \frac{T_0}{T_k - T_0} \tag{4}$$

where T_0 is the temperature of the evaporation section and T_k – the condensation end temperature.

When the room is set at a certain temperature, the lower the temperature T_k of the heat source at the outdoor condensation end, the greater the energy efficiency coefficient. In winter, the system achieves a heat pump cycle, where the temperature at the condensation end is the output hot water temperature, which is relatively stable. The higher the T_0 temperature at the outdoor air-cooled evaporation end, the greater the energy efficiency coefficient. The energy efficiency coefficient of the actual refrigeration cycle is lower than that of the ideal refrigeration or heating cycle, but its change trend is consistent with the temperature of the cold and heat sources [7].

Energy saving benefits compared to non-integrated systems

If an integrated system is not used, after research, in order to balance cooling, heating, hot water, and comfort, most households use air conditioning for cooling in summer, floor heating for heating in winter, and electric water heaters for domestic hot water. In summer, the COP of refrigeration can be taken as 3.5, and the efficiency of the water heater is 90%. The energy consumption in summer is the energy consumption of air conditioning refrigeration, water heater energy consumption, and refrigerator energy consumption. In winter, the efficiency of underfloor heating water heaters is 96%, and the efficiency of electric water heaters is 80%. The energy consumption in winter is the combination of underfloor heating energy consumption, water heater energy consumption, and refrigerator energy consumption. After calculation, the integrated system consumes 627.9 kWh in summer and 2173.6 kWh in winter. The energy consumption of non-integrated systems is 1268.8 kWh in summer and 11376 kWh in winter. After using the integrated system, it saves 50.6% energy in summer and 80.9% energy in winter. The entire heating and cooling season saves 77.8% energy. Significant energy-saving effect. In the non-cooling and heating seasons of spring and autumn, the integrated solar collector system collects 5158.5 kWh of heat from March 20th to June 18th, which is much higher than the required hot water volume of 665.54 kWh. From September 12th to November 29th, the heat collected was 3004.3 kWh, much higher than the required hot water heat of 537.3 kWh. Due to the system's heat storage function, there is no need to consume electricity in the spring and autumn seasons. Compared to the electric heating hot water mode, the integrated system can save 1198.85 kWh of electricity in non-cooling and heating seasons, with a 100% energy-saving rate [8-10]. The total energy consumption statistics are shown in fig. 4.

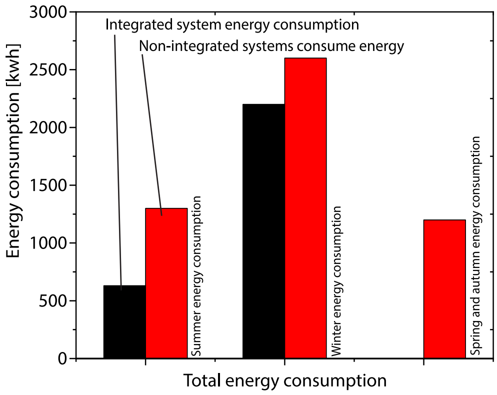

Figure 4. Overall energy consumption statistics

Conclusions

In recent years, under the rapid development of society, building heating engineering has attracted more and more attention, in order to effectively improve the performance and performance of building heating engineering projects. To ensure the quality, it is also necessary for relevant personnel to reasonably solve various hidden problems involved in the construction of the project, and carry out the construction technology as far as possible. Optimize and innovate to promote the sustainable and healthy development of the engineering industry. The BIM technology is currently a more advanced science and technology, applied to building heating engineering. Among them, it can play a positive role in improving the efficiency and effect of various works of the project, and can also effectively complete the design and construction of building technology. Avoid all kinds of dangers and hidden dangers.

The integrated heating, cooling and hot water system of BIM technology adopts the technology of cool storage and heat storage coupled with solar energy and heat pump technology. The system has simple structure, obvious energy saving effect, good environmental protection, and can adapt to various climates throughout the year. The introduction of underfloor heating also increases the comfort of residential buildings. The DeST software platform can simulate weather data well, and on this basis, it can analyze the energy consumption of the integrated system model, which is a relatively accurate evaluation method. The unit is cooled during the lowest temperature in summer and heated during the highest temperature in winter, which can effectively improve the overall operating efficiency. After changing the air-cooled condenser of the refrigerator to a water-cooled condenser, the cooling coefficient COP has increased. Compared to not using an integrated system, it can achieve an energy-saving rate of 81.9% throughout the entire refrigeration and heating season, with significant energy-saving effects.

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