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Article

Research on Optimal Matching of Heating Ventilation Air Conditioning System Based on Energy Saving Requirements

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Abstract: With the continuous development of society and the progress of science and technology, the living standards of the people also constantly improve, people pay more and more attention to the pursuit of material life, and the living space of everyday life and office space requirements are also rising, the air conditioning has become the essential in people's daily life a kind of electrical equipment. The traditional optimal matching methods of heating, ventilation, air conditioning (HVAC) system have common problems such as long matching time, low matching accuracy and many matching times. The application of the best matching method of HAVC system based on energy saving requirements is in line with the requirements of strengthening energy saving, and it is also an urgent need to actively respond to global climate change and establish a responsible image through energy saving. For this situation, this study proposes an optimal matching method for HVAC systems based on operating energy consumption. By analyzing the operation characteristics and energy consumption of HVAC refrigerator, calculating the operating energy consumption of HVAC system; Based on the results of energy consumption, analyzing the capacity matching relationship among photovoltaic modules, fans and batteries in HVAC system, to construct the best matching model between the three groups of devices. The experimental results show that the method proposed in this study has shorter matching time, higher matching accuracy and fewer matching times. This study constructs a new optimal matching model, which has better energy-saving effect and the study's results have better engineering reference value. It can not only effectively reduce energy consumption, but also effectively protect limited natural resources, which has both natural and social significance.

Keywords: Energy saving requirements; heating ventilation air conditioning system; optimal matching

1 Introduction

The optimal matching refers to finding the best matching result based on matching algorithm or some rules, which is generally used in pattern recognition, image processing and other fields. After years of exploration, designers in the field of heating and ventilation have continued to improve energy efficiency, and try to avoid unnecessary energy waste by a series of technical and organizational measures within the social and environmental limits and in all aspects of energy production and application [1,2]. The working principle of HAVC is that the refrigerant in the evaporator of the refrigeration unit carries on the heat exchange with the frozen water and vaporizes, thus reducing the temperature of the frozen water [3–5]. The vaporized refrigerant is then turned into a high-temperature and high-pressure gas by the compressor, when it passes through the condenser of the refrigeration unit, it is cooled by the cooling water from the cooling tower, and changes from gas to a low temperature and low pressure liquid. The chilled water is sent to the heat exchanger of the air treatment unit through the chilled water pump [6]. Exchange cold and heat with mixed air to form a cold air source, which is sent to the room to be adjusted through the air supply pipeline. In this way, the heat of the room is taken away by the cooling water in summer and released into the air as it flows through the cooling tower, working principle of HVAC shown in Fig. 1.

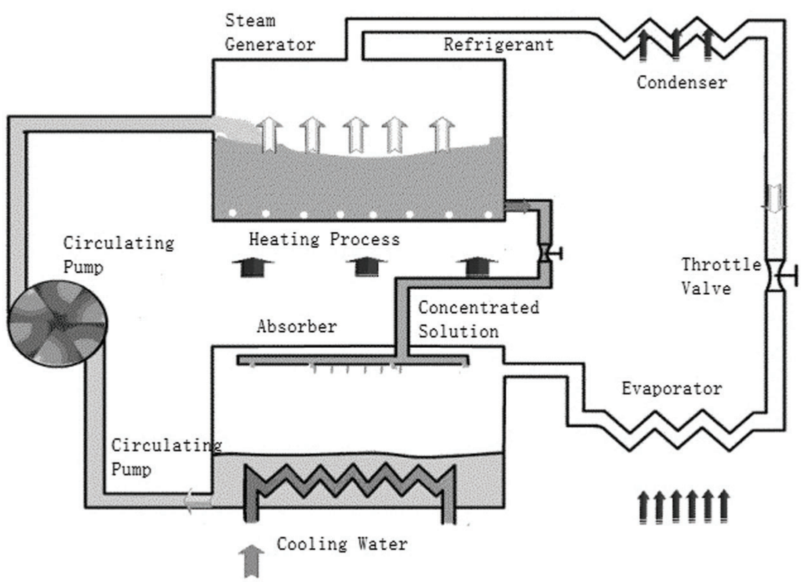

Figure 1: Working principle of HVAC

During the HVAC system design process, energy saving is also the responsibility of HVAC professionals [7,8]. According to the research results of the HVAC industry, the important measures to reduce building energy consumption and protect the environment include taking necessary energy-saving measures to reduce its energy consumption and impact on the environment which can save energy above 50% at most [9,10]. In existing air-conditioning systems, by adopting energy-saving technologies and taking different energy saving measures according to the climate and natural environmental characteristics of different regions, not only can it effectively reduce energy consumption, but also effectively protect the limited natural resources with taking advantage of the powerful natural conditions. Promoting the application of new energy-saving technologies can improve the environment with both natural and social significance [11].

Air conditioning is the main method of indoor cooling in summer and heating in winter, and HVAC can choose the best working mode according to the size of indoor space, temperature and airflow. Airflow is closely related to outdoor temperature, so there is a distribution relationship between water temperature and outdoor temperature, Scatter diagram of water supply temperature and outdoor temperature shown in Fig. 2. In order to meet supply demand, it needs to match with HVAC system [12,13], but among the best matching methods of HVAC system at this stage, there are common problems such as long matching time, low matching accuracy, many matching times and so on. Under the circumstances, how to effectively propose a matching method with good matching effect has become an urgent problem to be solved in today's society [14,15]. Bryan [16] proposed a capacity matching method for HVAC system based on unit optimization. This method matched the load deviation of HVAC system, unit adjusting capacity, unit climbing capacity and equivalent load fluctuation capacity with selecting the unit capacity matching parameters of HVAC system, and the aim was minimum air volume to build capacity matching model, and to use particle swarm optimization algorithm to solve it and complete the matching. This method had higher matching accuracy, but the matching completion time was longer. He et al. [17] proposed a capacity matching method based on gas triple supply heat pump. The method was based on the installed capacity of HVAC system, and the calculation method of present value during the investigation period was combined with the frequency statistics of each load interval of gas equipment to obtain the relevant benefits of operating hours under full load of equipment by different capacity matching methods, which could be used to select the best matching scheme by comparison. This method had high matching efficiency, but the matching accuracy was low. Huo et al. [18] proposed a device capacity matching method based on multi-time node. This method established a multi-objective optimization model for equipment capacity matching, and the genetic algorithm was used to solve the model to get the optimal solution and complete the matching. This method had high matching efficiency, but it take a long time to complete matching.

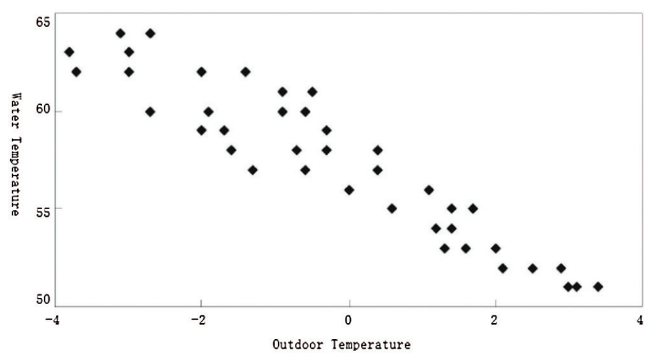

Figure 2: Scatter diagram of water supply temperature and outdoor temperature

In order to avoid the above disadvantages in traditional methods, this study proposes an optimal matching method for HVAC systems based on multiple models. The experimental results shows that the proposed method has shorter matching completion time, higher matching accuracy and fewer matching times.

2 Energy Consumption Calculation of HVAC System

2.1 Operating Energy Consumption of HVAC System

With the rapid development of national economy, energy and environmental problems are increasingly acute, and with the rapid development of urbanization and the improvement of people's living standards, building energy consumption accounts for an increasing proportion of total energy consumption, in the developed world, it is 40%, and energy consumption for HVAC systems accounts for 30%–50% of building energy consumption, and it is increasing year by year [19,20]. In order to maintain the proper temperature and humidity in the air environment inside the building, HVAC systems are often used in modern buildings to ensure this demand and the energy consumed is the energy consumption of the HVAC system. This part of energy consumption includes energy consumption caused by building cooling and heat load, energy consumption caused by fresh air load and energy consumption of conveying equipment. The main factors that affect the energy consumption of HAVC system are outdoor climate conditions, interior design standards, envelope structure characteristics, indoor personnel and equipment lighting, the setting of fresh air system and so on. The energy consumption of HVAC systems also has several characteristics, which are manifested in: The unreasonable design, selection and operation management of the system will reduce the energy efficiency. The heat and cold energy required to maintain the indoor air environment is of low grade and seasonal. This makes it is possible to use natural energy sources such as solar energy, geothermal energy, waste heat and shallow soil heat storage to meet the requirements when conditions are available. The treatment of cold heat involved in HVAC systems is usually in the form of exchange, which can use cold and heat recovery measures to reduce system energy consumption and effectively use energy.

By analyzing the operational characteristics of HVAC refrigerator and energy consumption of air-conditioning equipment (shown in Fig. 3), calculating the operating energy consumption of HVAC system, and providing basis for capacity matching of air conditioning equipment, the specific process is as follows:

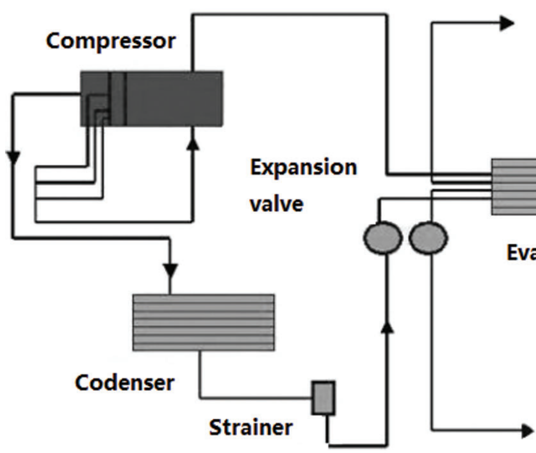

Figure 3: Working principle of air conditioning refrigerator

The operating efficiency of HVAC system is mainly determined by the operating efficiency of air-conditioning chiller and cooling tower, and the energy consumption of the chiller of the warm air conditioning equipment accounts for more than 90% of the total energy consumption of the whole air conditioning system, and it must analyze the operating characteristics of the air conditioner refrigerator; There is a certain correlation between the operating characteristics of HVAC refrigerator and the operating load, when the HVAC refrigerator is running at full load, the refrigerator is the most efficient, and when operating under partial load, the efficiency of the refrigerator is lower than that under full load.

Because HVAC has more time under partial load operation, the annual energy consumption of the air-conditioning system is related to the operating characteristics of the refrigerator under partial load.

It is assumed that the rated power of HVAC is expressed as P_0, and rated cooling capacity is expressed by Q_0, and the total annual operating hours of HVAC is expressed as T_0, and the annual energy consumption of HVAC refrigerator is expressed by W. The calculation formula of annual energy consumption of HVAC refrigerator is:

$$W = \sum_{i=1}^{N} P_i T_i \quad (1)$$

In the formula, W represents the total annual energy consumption of HVAC; N represents the number of partial load interval; P_i and T_i respectively represent the power and running time of the refrigerator under partial load Q_i.

$$W = T_0 P_0 \sum_{i=1}^{N} P_i T_i \tag{2}$$

In the formula, P_i represents the power percentage of HVAC equipment under partial load q_i and is the characteristic parameter of HVAC equipment; t_i Represents the percentage of total operating time of HVAC refrigerator under partial load q_i; P_i and t_i are both functions of the partial load q_i of the refrigerator.

Therefore, the calculation formula of the average annual operating power of HVAC equipment is:

$$P = \frac{W}{T} = T_0 P_0 \sum_{i=1}^{N} P_i T_i \tag{3}$$

According to the above analysis, the average annual operating power of HVAC equipment is obtained. By comparing the operating power of various types of air-conditioning equipment, the operating energy consumption of HVAC equipment can be calculated, which provides a data reference for the research on the best matching method of equipment capacity multi-association combination.

Based on the calculation of the operating energy consumption of HVAC system, the capacity matching relationship between photovoltaic modules, fans and batteries in HVAC system are analyzed, and the optimal matching of the capacity and multiple associations among the three groups of system is constructed. The specific process is as follows: based on the electronics theory, the photovoltaic components in the HVAC system are analyzed, and the I-V characteristic curve equation of the photovoltaic cells of the HVAC equipment is:

$$I = I_L - I_0 \exp\left[\frac{q(V + IR_S)}{AKT} - 1\right] \frac{V + IR_S}{R_{sh}} \tag{4}$$

In the formula above, I represents the working current; I_L represents the photocurrent; I_0 represents the reverse saturation current; q represents electron charge of photovoltaic modules in HAVC system; K represents Boltzmann constant; A represents diode factor; R_s represents series resistance.

3 Experiment and Simulation Prove

In order to verify the comprehensive effectiveness of the proposed optimal matching method for HVAC systems based on operating energy consumption and energy saving requirements, it needs to perform a simulation experiment, and the operating system is Windows7, and the memory is 36 GB. The proposed method is compared with the wind grid motor capacity matching method based on unit optimization and the capacity matching method based on gas triple supply heat pump.

The matching accuracy (%) of the proposed method was compared with the wind grid motor capacity matching method based on unit optimization and the capacity matching method based on gas triple supply heat pump, and the experimental results are shown in Tab. 1, and the method 1 represents the proposed method; Method 2 represents the wind grid motor capacity matching method based on unit optimization, and this method is based on unit optimization to optimize the matching of wind turbine capacity, but compared with the proposed method, its matching accuracy is lower; Method 3 represents the capacity matching method based on gas triple supply heat pump, and the triple heating system consists of a generator residual heat addition device and a peak-shaving device, which are easily affected by various external factors. Under the condition of the same number of samples, this method has the lowest matching accuracy. The matching accuracy of different methods is shown in Tab. 1:

According to Tab. 1, the matching accuracy of the three methods also increases with the number of samples continues to increase. When the number of samples is 20, the matching accuracy of the proposed

Table 1: The matching accuracy of different methods

Number of samples	Matching accuracy (%)		
	Method 1	Method 2	Method 3
20	99.5	99.00	98.00
40	99.95	98.88	97.75
60	99.88	98.67	97.48
80	99.76	98.35	97.12

method is 0.50% and 1.50% different from that of the wind grid motor capacity matching method based on unit optimization and the capacity matching method based on gas triple supply heat pump. When the number of samples is 40, the matching accuracy of the proposed method is 1.07% and 2.20% different from that of the wind grid motor capacity matching method based on unit optimization and the capacity matching method based on gas triple supply heat pump. When the number of samples is 60, the matching accuracy of the proposed method is 1.21% and 2.40% different from that of the wind grid motor capacity matching method based on unit optimization and the capacity matching method based on gas triple supply heat pump. When the number of samples is 80, the matching accuracy of the proposed method is 1.41% and 2.64% different from that of the wind grid motor capacity matching method based on unit optimization and the capacity matching method based on gas triple supply heat pump. When the number of samples increases from 20 to 80, the matching accuracy of the proposed method is always above 99%, and the matching accuracy of the wind grid motor capacity matching method based on unit optimization is always within the range of 99.00%~98.35%, and the matching accuracy of capacity matching method based on gas triple supply heat pump is always within the range of 98.00%~97.12%. The comparison results show that the proposed method has the highest matching accuracy, and it has certain practical value.

Performing the matching completion time (s) comparison experiment among the proposed method, the wind grid motor capacity matching method based on unit optimization and the capacity matching method based on gas triple supply heat pump. The experimental results of 3 matching methods are shown in Fig. 4.

Fig. 4 shows that the completion time of the three methods also increases with the occurrence of different degrees with the number of samples increases. Fig. 4(a) represents the completion time of the proposed method, when the number of samples increases from 0 to 100, the matching time of the proposed method fluctuates within the range of 25 s to 35 s, and the fluctuation range is relatively gentle; Fig. 4(b) represents the completion time of the wind grid motor capacity matching method based on unit optimization, when the number of samples increases from 0 to 100, the matching time of the wind grid motor capacity matching method based on unit optimization fluctuates within the range of 30 s to 65 s, and the fluctuation range has been increasing; Fig. 4(c) represents the completion time of the capacity matching method based on gas triple supply heat pump, when the number of samples increases from 0 to 100, the matching time of the capacity matching method based on gas triple supply heat pump fluctuates within the range of 45 s to 95 s, and when the fluctuation range increases from 0 to 40, the completion time is on the rise, but when the number of samples increases from 40 to 60, the fluctuation amplitude decreases slightly and then increases rapidly; The results of comparison shows that the matching time of the proposed method is short, the matching time of the wind grid motor capacity matching method based on unit optimization is more longer, and the matching time of the capacity matching method based on gas triple supply heat pump is the longest.

Conducting the matching times experiment among the proposed method, the wind grid motor capacity matching method based on unit optimization and the capacity matching method based on gas triple supply

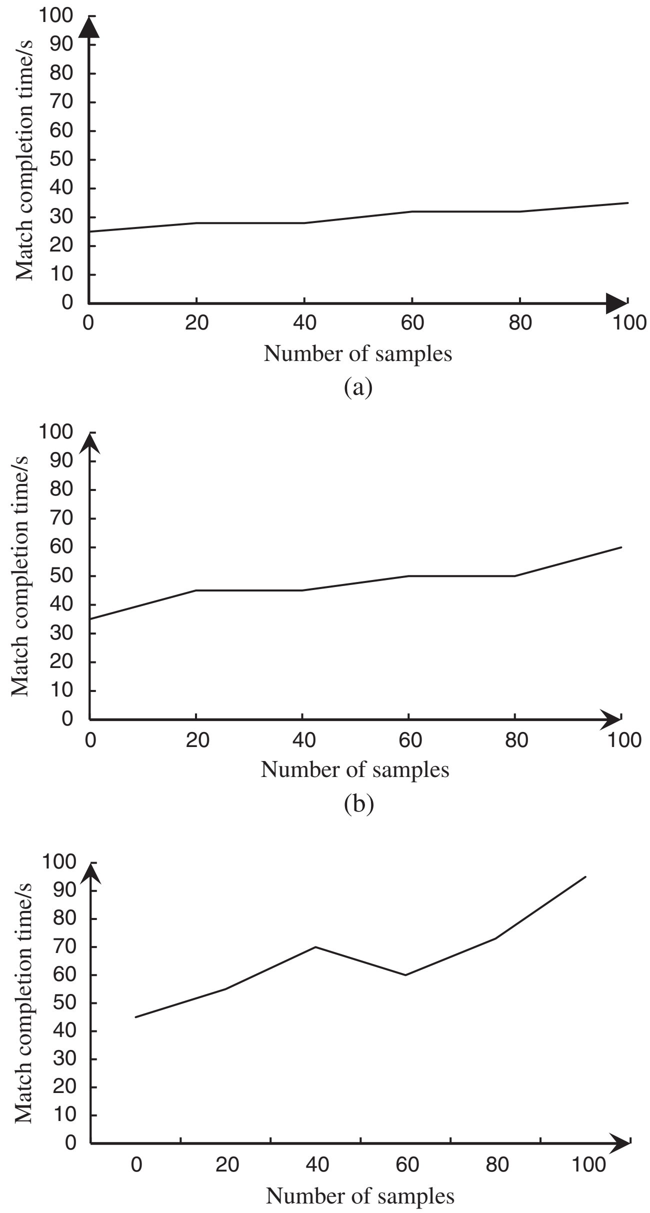

Figure 4: The experimental results of 3 matching methods. (a) Completion time of the proposed method. (b) Completion time of the wind grid motor capacity matching method based on unit optimization. (c) Completion time of the capacity matching method based on gas triple supply heat pump

heat pump, the experimental results are shown in Tab. 2. In the Tab. 2, method 1 represents the wind grid motor capacity matching method based on unit optimization; Method 2 represents the capacity matching method based on gas triple supply heat pump; Method 3 represents the proposed method. The comparative experimental results of matching times among different methods are shown in Tab. 2:

According to Tab. 2, the matching times of the HVAC system capacity with the proposed method are obviously lower than that of the wind grid motor capacity matching method based on unit optimization and the capacity matching method based on gas triple supply heat pump. The results of the comparison

Table 2: The comparative experimental results of matching times among different methods

Type	Matching times		
	Method 1	Method 2	Method 3
ZBJJ-S-C-350	12112	12081	10355
ZBJJ-S-K-210	56698	56015	45881
30HXC250AH	3378	3371	2816

shows that the proposed method has the least number of matching times, which can improved matching efficiency and can meet the energy saving requirements. The matching times of the wind grid motor capacity matching method based on unit optimization is more, and the matching times of the capacity matching method based on gas triple supply heat pump is the most.

In order to improve the energy-saving matching of HVAC systems, it is necessary to proceed from three perspectives. To consider how closely the system matching function fits the actual situation, that is to modify and improve the existing match according to the actual situation instead of requiring the actual situation to change with the match, and this order of precedence is something that all match-makers must keep in mind. For example, the temperature difference between day and night and four seasons varies greatly in some areas, while the temperature in some areas is relatively flat in a year. These specific environmental differences are the basis for the matching personnel to adjust the specific system. To perfect the matching itself, it should try to avoid the loopholes and deficiencies in the matching, so that the existing technical level can meet the matching requirements to ensure that the matching effect can be truly realized, and to truly achieve the goal of energy saving. To find the balance between matching and function, it is necessary to achieve the effect of energy saving without affecting the application of air conditioning. And it is necessary to have the courage to break through the traditional thinking to truly achieve this and not be limited to the contradictory relationship. Through the reference of different energy sources and the updating of the technology, the purpose of energy saving can be achieved without affecting the application effect of the air conditioning system. In addition, the design of HVAC should be dynamically managed, compared with the actual implementation, the design of HVAC is in accordance with the PDCA cycle to find problems and take corrective measures in time according to the design plan.

4 Conclusion

HVAC system consumes a large amount of energy in practical application, as the important aspect of building energy saving, energy saving of HVAC system is related to people's health and work efficiency, and is related to energy security, resource consumption and environmental pollution. Therefore, it needs to be fully aware of the importance of the HVAC system energy saving, and to take efficient energy-saving matching measures to continuously improve the environmental benefit and social benefit of HVAC system. The traditional optimal matching methods of HVAC system have common problems such as long matching time, low matching accuracy and many matching times, and in view of the existing problems, this study proposes the optimal matching of HVAC system based on energy saving requirements. The experimental results show that the proposed method has shorter matching time, higher matching accuracy and fewer matching times, and the application of the method protects the environment, and can achieve energy saving and emission reduction. From the perspective of current situation and trend of social development, the application of energy-saving technology is an inevitable trend of future development. In the application of HVAC system, more attention should also be paid to this issue. It is hoped that through the development and application of energy-saving technology, the matching and application effect of HAVC system will be better.

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