

# Analysis and Application of Energy-Saving Automatic Control Technology for HVAC System

Wang Zhang, Long Sun, Binbin Li, Xin Tan, Shihua Liang, Wei Hong\*  
Shandong Resources and Environment Construction Group Co., Jinan, Shandong, China  
\* Corresponding author: Wei Hong

**Abstract:** In building project, the HVAC system is an important component and plays a decisive role for the comfort of the building. In order to achieve the purpose of energy saving and consumption reduction, it is necessary to reasonably apply energy-saving automatic control technology, so as to improve the overall quality of the building. In view of the application of HVAC energy-saving automatic control technologies, this paper expounds the basic principles of HVAC energy-saving automatic control design, analyzes the main problems existing in the application of HVAC energy-saving automatic control technology, and analyzed the optimization strategies and proposes improvements of HVAC energy-saving automatic control technologies.

**Keywords:** HVAC; energy-saving automatic control; environmental protection

## 1. Introduction

With the rapid development of society, HVAC (Heating, Ventilating and Air Conditioning) system has gradually become one of the most widely used facilities in urban buildings. HVAC mainly refers to the electrical equipment for the purpose of providing the masses with appropriate temperature and high quality life. With three functions of ventilation, heating and air conditioning, the HVAC system not only to improve people's indoor living environment, but also greatly enhanced the quality of life<sup>[1]</sup>. While the number of HVAC production is increasing, product models are also constantly being updated. Large amount of energy consumption is the problem that cannot be ignored in the application of HVAC<sup>[2]</sup>. Optimization design and automatic control are important means to improve energy saving of HVAC<sup>[3]</sup>. Therefore, in the system design, the rational use of energy-saving automatic control technology is conducive to improve the overall quality of the building, and to promote the natural ecology, environmental protection and sustainable development.

With increasing environmental concerns, the environmental regulations has become more and more strict, HVAC system are faced with how to reduce the large amount of energy consumption. Energy-saving and environmentally friendly technologies are intended to develop rapidly in all areas of social life. Energy saving

automatic control of HVAC system is an effective way to save resources. The effective implementation of energy saving automatic control can reduce the power consumption to the greatest extent, enhance the efficiency of cold storage and heat storage, and greatly improve the utilization rate of resources<sup>[4]</sup>. However, there are still many problems in the application of energy-saving automatic control in HVAC system. This paper expounds the control method of HVAC automatic control system and basic principles of HVAC energy-saving automatic control design, analyzes the main problems existing in the application of HVAC energy-saving automatic control technology, and analyzed the optimization strategies and proposes improvements of HVAC energy-saving automatic control technologies.

## 2. The Control Method of HVAC Automatic Control System

### 2.1. Development and Characteristics of Automatic Control Theory in HVAC

With the development of automation control theory, automatic control for HVAC system has also been revolutionary development. In the 1980s, HVAC equipment was almost in a simple ON/OFF control mode, in other words, the room temperature was monitored and controlled by components such as pressure relays or thermal relays.

Then PID controller and its modification type had been generally applied in modern society. The PID controller with simple structure and strong robustness achieves good control effect. So that the use of pure PID controller in HVAC system had been up to 84%, and more than 90% including the improved type<sup>[5]</sup>. The use of PID controller in Japan has reached nearly 84.5%. At present, the newly developed intelligent control theory has been applied to the field of HVAC, including fuzzy control, neural network control and genetic algorithm<sup>[6]</sup>.

### 2.2. The Application of Automatic Control Theory in HVAC

#### 2.2.1. Fuzzy Control

Fuzzy control is better than traditional PID control in energy saving and comfort performance in HVAC system. Fuzzy control has strong robustness and control rules are

easy to be generated. However, depending on the experience of experts or operators, the membership function and control rules obtained may be inaccurate and affect the control results<sup>[7]</sup>. Due to the control rules of conventional fuzzy frequency conversion air conditioning have been determined in advance, when the range of environmental temperature change is larger, the control mutation (up and down) will occur, not only a waste of energy, but also make people feel uncomfortable.

### 2.2.2. Neural Network control

Neural network control is now applied in the field of HVAC. Neural network control can be used in complex environment and multi-objective control with high accuracy and fault tolerance. However, the convergence speed is slow, the network structure is difficult to determine, and the initial connection weight and threshold selection are easily affected<sup>[8]</sup>.

The neural network is superior to the traditional PID control in control precision, and can obviously reduce the overshoot of the system as fuzzy control, and achieve the purpose of energy saving and comfort. However, there are few examples of artificial neural network control applied to practical engineering in the field of HVAC, and further research is needed.

### 2.2.3. Genetic Algorithm

Genetic algorithm (GAs) appeared in the 1960s and was proposed by Professor Holland of University of Michigan. Deeply influenced by Darwinian evolution, Professor Holland has been devoted to exploring a stochastic search method that is independent of the mathematical model of the problem and has strong spatial dynamic search capability<sup>[9]</sup>.

The PID control effect of genetic algorithm is very good, and its output response is faster than conventional PID control, the transition time is shorter and smoother, and the overshoot is lower. When genetic algorithm is applied to intelligent control algorithm, it can obviously improve control speed and efficiency. However, its application in HVAC system is less, and relevant theoretical research still needs to be strengthened.

## 3. Basic Principles of Energy Saving Automatic Control Design for HVAC System

In order to make the automatic control system in the HVAC system play a better role in energy saving and environmental protection, relevant design principles should be summarized and applied.

### 3.1. Integrity

In order to realize the energy saving of HVAC, the principle of integrity must be taken as its foundation. In the process of system design, the significance of energy saving and automatic control should be deeply understood and the overall design of HVAC should be considered. At the same time, according to the relevant policies and calls of the national energy conservation and emission reduction, the design of air conditioning energy-saving should consider with safety, economy,

rationality and comfort. The design process of HVAC energy saving personnel should have a higher professional level requirements, but also should have a forward-looking design vision.

### 3.2. Dynamic

Because of the high complexity<sup>[10]</sup>, wide range of fields and scope covering, the overall design and local energy-saving automatic control system must comply with the national or local energy saving policy standards, including local geographical environment and other natural factors. To adhere to the dynamic of energy saving and automatic control design of HVAC engineering, we should keep pace with The times and optimize the scheme according to the actual situation, so that HVAC system can meet the energy saving requirements as much as possible in the constantly changing external environment.

### 3.3. Adaptability

With the steady progress of “Carbon neutral and carbon peak”, China has been promoting green and low-carbon energy development, and new technologies of HVAC system have been developed and gradually popularized. In the design automatic control system of HVAC energy saving, the system adaptability of new technology application should be fully considered, and the core technology of automatic control system should be upgraded, so as to reduce energy consumption of buildings as much as possible and give better play to the role of automatic control system. Therefore, in order to achieve the goal of energy conservation, environmental protection and economy, professionals in the automatic control design, should always consider the application of new energy and new technology.

## 4. Main Problems Existing in the Application of HVAC Energy Saving Automatic Control

### 4.1. The Unreasonable Equipment Selection and the Design Parameters

The unreasonable selection of HVAC equipment is not conducive to the design and application of energy saving automatic control system. In the application of HVAC energy saving, the most obvious problem is the mismatch of cold and heat source and terminal system equipment selection<sup>[11]</sup>. HVAC circulating cold and heat source is the basis of the whole system design, the energy consumption of circulating cold and heat source accounts for about 40% of the overall energy consumption. The use of matching circulating cold and heat source can effectively improve the energy utilization rate, save the overall operation cost. However, in the design of many HVAC projects, comprehensive factors are often not taken into account. For example, renewable energy, such as solar energy and wind energy, is not considered as far as possible combined with the actual situation. At the same time, HVAC air conditioning box, fan disk and other energy equipment matching is not properly matched. It directly leads to the inadaptability of the circulating cold and heat source selected in the system design, and

the overall system equipment to temperature and humidity changes, and the inevitable problems such as difficult cooling, low wind speed, waste of electric energy and so on.

Unreasonable parameter design often exists in HVAC energy saving automatic control system. In HVAC system design, most engineering control parameters were not calculate on indoor actual temperature and humidity, or indoor parameter calculation values occur when too high in winter or too low in summer, which shows the negligence to the normative design detail. And the influence of the structure of buildings is not considered, as will as the whole automatic control system in detail, result in the poorer function performance of automatic control, which cause extra energy waste.

#### 4.2. The Overall System is Unreasonable and the Operation is Not Flexible

In the design of energy saving automatic control system of HVAC system, the integrity of the whole system is unreasonable, and the operation is usually not flexible. With the development and utilization of new energy saving technologies and green technologies, air conditioning system technologies are further developed. But in the practical application, in-depth research on new energy technologies are lack for automatic control system designers, as well as the adaptive adjustment, resulting in unreasonable design in automatic control systems, which affect the use of new air conditioning functions and indirectly lead to energy waste.

Due to different operating conditions at different stages and different operating time in different air conditioning areas, air conditioning control requirements are inconsistent. In HVAC control design of energy conservation. If the automatic control system is not designed to operate flexibly, or design of the monitoring point is not in place, the HVAC system will not function effectively, and cannot make proper adjustment according to the change of parameters such as indoor and outdoor temperature or humidity, which directly resulting in energy waste.

#### 4.3. The Realization Effect of HVAC Energy Saving Technology Need to be Improved

At present, HVAC energy saving automatic control technology is developing as a whole, but it is still relatively slow. In architectural design application, the actual application of the energy-saving control technology will be affected by the usage environment and the installation of HVAC systems. The application of energy saving automatic control technology is limited by monitoring and operation software programming, sensor signal access, information collection and feedback and other technologies, which also require advanced development and technical support. The related technologies are still in the development stage, which will affect the application effect of energy saving automatic control technology of HVAC.

#### 4.4. The Comprehensive Quality of Relevant Personnel is Relatively Low

In the practical application of energy saving automatic control technology of HVAC, the technical and comprehensive quality of the staff will directly affect the realization of energy saving automatic control effect<sup>[12]</sup>. In the installation process of specific projects, the professional level of some staff was low and the comprehensive literacy is poor, which will reduce the energy saving effect of HVAC system. Advanced energy saving automatic control system needs professional training for relevant staff. Low comprehensive quality of relevant staff will affect the application of HVAC energy saving automatic control system.

### 5. Optimization Strategies and Proposes Improvements

#### 5.1. Improve the Environmental Protection Requirements

With the continuous improvement of energy conservation and environmental protection requirements, in the future, the improving energy efficiency becomes the first functional requirement of HVAC energy saving automatic control system. The basis of energy saving automatic control system is to improve the diversity of HVAC system. By overcoming the problem of high energy consumption of air conditioning, the new technologies for multi-layer utilization and recycling of energy have been developed, so as to achieve environmental protection under the premise of energy conservation and emission reduction.

#### 5.2. Improve the Comprehensive Quality of Designers

The quality of designers directly affects the quality of design. Only by constantly strengthening the professional quality of designers and injecting the green and low-carbon concept into the design system, can the requirements of energy consumption reduction, energy saving and environmental protection be achieved in the actual design and application process<sup>[13]</sup>. For HVAC automatic control system designers, to strengthen the study of new technologies and new theories, deepen the design depth of automatic control strategy, optimize control parameter monitoring, the automatic control system for HVAC system energy saving regulation and optimization operation can be achieved.

#### 5.3. Enhance the Debugging of Automatic Control System

The debugging of HVAC automatic control system is very important for the whole system<sup>[14]</sup>, which is the key premise to guarantee the automatic control effect of the energy saving system. After the completion of HVAC automatic control system, due to the limitation of cost and time, the debugging process is often abridge or perfunctory. Therefore, automatic control parameters have not been optimized and set appropriately. Through enhancing the system debugging process, strengthening the system running condition setting and maintenance, and confirming the energy saving effect, it can further improve the ability of relevant designers to solve the problems in the actual operation process, and effectively

avoid the increase of energy consumption caused by sensor, actuator failure and other problems.

#### 5.4. Establish the Performance Guarantee Method for HVAC Automatic Control System Applicable to the Operation Stage

Poor maintenance of HVAC automatic control system and incorrect control strategy are main reasons for increasing energy consumption of HVAC system instead of decreasing<sup>[13]</sup>. Therefore, the automatic control system for energy saving in HVAC can be established through more sensitive detectors development, more accurately sensor setup, actuator fault intelligent diagnosis model development, timely faults find methods, avoid control errors conduction, and the application of data mining technology in the operation data analysis. Only in this way can the operating level of the system be evaluated correctly and the incorrect control be found in time, and avoid energy waste as much as possible.

### 6. Conclusion

HVAC is a common heating and refrigeration equipment in the daily life of residents. The application of HVAC energy saving automatic control system is conducive to saving energy, reducing pollution to the environment and improving economic benefits. Energy saving automatic control system plays an indispensable role in the design of HVAC system. With the continuous improvement of basic theory and the manufacturing technology, the application level of energy saving automatic control system in HVAC system will gradually improve. By improving the overall technology of HVAC system, and constantly strengthening the technical level of designers, carrying out more detailed control strategy design, and strengthening the operation and debugging of the system, the application of energy saving automatic control system will be more effective and efficiency. Through the continuous promotion of social development, more mature technologies will enhance the application performance of HVAC automatic control system, which will make outstanding contributions to the sustainable development of economy and environmental protection.

### References

- [1] Ye Shuai, Yang Zhen, Li Zai-peng, et al. Analysis of environmental protection and energy saving technology in HVAC refrigeration system. *Resource conservation and Environmental Protection*, 2021, 5:1-2.
- [2] Afram A, Janabi-Sharifi F. Theory and applications of HVAC control systems—A review of model predictive control (MPC). *Building and Environment*, 2014, 72: 343-355.
- [3] Shi Yuan-yuan, Analysis of Energy Saving and Environmental Production Technology in HVAC Refrigeration System. *Applied Energy Technology*, 2020, 4: 34-38.
- [4] Fong K F, Hanby V I, Chow T T. HVAC system optimization for energy management by evolutionary programming. *Energy and Buildings*, 2006, 38(3): 220-231.
- [5] Johansson K H, James J B, Bryant G F. Multivariable controller tuning. *The 17th American Control Conference*, Philadelphia, PA, 1997.
- [6] Tang Wei-jie, Wang Hai-tao. Literature Review of Conventional and Intelligent Control Methods of HVAC System. *Industrial Control Computer*, 2021, 34(10): 48-50.
- [7] Zheng Bin-hui. *The Research and Application of Fuzzy Control in HVAC and Room System*. Zhejiang University, 2012.
- [8] Wang min, HVAC Control System Based on Neural Network Optimizing PID Controller. *Modern Electronics Technique*, 2017, 40(23): 137-139, 143.
- [9] Ma qiang. *The Research and Application of Genetic Simulated Annealing Algorithm in Water System of HVAC*. Zhejiang University, 2012.
- [10] Afram A, Janabi-Sharifi F. Review of modeling methods for HVAC systems. *Applied Thermal Engineering*, 2014, 67(1-2): 507-519.
- [11] Tashtoush B, Molhim M, Al-Rousan M. Dynamic model of an HVAC system for control analysis. *Energy*, 2005, 30(10): 1729-1745.
- [12] Mathews E H, Botha C P, Arndt D C, et al. HVAC control strategies to enhance comfort and minimise energy usage. *Energy and buildings*, 2001, 33(8): 853-863.
- [13] Liu Qiu-qiong, Li Zhi-sheng. Development and application of Automatic control in HVAC. *Building Energy Efficiency*, 2017, 45(7): 104-107.
- [14] Matt Wallace, Ryan McBride, Siam Aumi, et al. Energy efficient model predictive building temperature control. *Chemical Engineering Science*, 2012, 69: 45-58.