

# Study on the Impact of Humidity Control Strategy on Energy Saving Effect of Centralized Central Air Conditioning System

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**Abstract:** As an indispensable part of modern buildings, centralized central air conditioning systems play an important role in maintaining the comfort and air quality of the indoor environment. However, with the increasing energy consumption, how to improve the energy efficiency ratio of air conditioning systems and reduce energy consumption has become an important issue in research and practice. The purpose of this paper is to discuss the impact of humidity control strategies on energy saving in centralized central air conditioning systems, with a view to providing a theoretical basis and practical guidance for realizing building energy efficiency

**Keywords:** Centralized central air conditioning system; Energy saving potential; Humidity control strategy; Energy saving effect assessment

**Online publication:** August 7, 2025

## 1. Introduction

The basic concept of centralized central air conditioning systems and their significance for building energy efficiency are introduced. Then, some existing issues in humidity control of centralized central air conditioning systems and their impact on energy consumption will be summarized. Additionally, in this chapter, the author will explain the research background and significance, and define the research objectives and methods, thus laying the foundation for the in-depth analysis in the following sections. At the end of the article, we will summarize the main research findings, highlight the innovations and practical application value of the research, and provide some suggestions for future research trends and potential optimization strategies. Through this study, it is hoped that it can serve as a useful reference and guidance for the energy-saving design and operation management of centralized central air conditioning systems.

## **2. General situation of centralized central air conditioning systems**

### **2.1. Operating principle of the system**

The centralized air conditioning system is one of the widely used air conditioning systems in commercial buildings, public facilities, and residential areas. This system operates primarily based on air processing and distribution mechanisms. The system consists of a centralized air processing unit that filters, cools, heats, or dehumidifies the air, and then distributes the processed air to various rooms or areas through a duct system. The core components of this process include a compressor, evaporator, condenser, and expansion valve, which work together to perform thermal and humidity treatment on the air.

The core of the system's working principle lies in its ability to control air temperature and humidity. By adjusting the operating states of the evaporator and condenser, the system can absorb or release heat, thereby regulating the temperature of the air. Simultaneously, by adjusting the opening of the expansion valve to control the flow of refrigerant, it can also influence air humidity. This combined control of temperature and humidity enables the centralized air conditioning system to provide a suitable indoor climate for various environmental needs.

In addition, the operational mechanism of the centralized air conditioning system also encompasses the management of fresh air and return air. Introducing fresh air ensures fresh indoor air, while recycling return air is conducive to improving energy efficiency. By accurately controlling the ratio of fresh air to return air and managing heat and humidity, the system can further optimize air conditioning performance and achieve a higher energy efficiency ratio.

From the perspective of energy conservation, the principle of centralized air conditioning systems offers various possibilities. For instance, using variable frequency technology to adjust the operating speed of compressors allows for system output adjustment based on actual load requirements, thereby reducing energy consumption <sup>[1]</sup>. Additionally, utilizing intelligent control systems to monitor and adjust the operating conditions of air handling units in real time enables more refined energy management and further enhances energy-saving effects <sup>[2]</sup>.

### **2.2. Analysis of system energy-saving potential**

Centralized central air conditioning systems are an indispensable part of modern buildings, providing a comfortable indoor environment for people while also generating significant energy consumption. Therefore, an in-depth analysis of the potential for energy savings in these systems is crucial for achieving energy conservation and emission reduction in buildings. This article will discuss the energy-saving potential of centralized central air conditioning systems as follows.

Initially, the design and configuration of the system are directly related to energy-saving effects. Reasonable system design can reduce energy consumption while meeting operational requirements. For instance, using high-efficiency refrigerants, optimizing pipeline layout, and designing heat exchangers can all improve the system's energy efficiency ratio.

Secondly, considering that system operation management is also crucial for energy-saving effects, we can dynamically adjust the system by utilizing intelligent control methods such as variable frequency technology, load forecasting, and demand response, thereby reducing unnecessary energy consumption <sup>[3]</sup>.

Furthermore, it is crucial to maintain and optimize the system. Regular maintenance ensures that all components in the system work efficiently, while system optimization can further improve energy efficiency

through technological upgrades and modifications.

Ultimately, user behavior plays a significant role in energy-saving effects that cannot be overlooked. Measures such as enhancing users' awareness of energy conservation and adopting reasonable usage habits can effectively reduce system energy consumption.

### **3. The role of humidity control strategy in the energy-saving effect**

#### **3.1. Basic principles and methods of humidity control**

Centralized central air conditioning systems play a pivotal role in modern buildings, providing a comfortable indoor environment while also being significant energy consumers. Among various energy-saving measures, humidity control strategies have garnered widespread attention due to their significant impact on energy consumption. This section discusses the principles and methods of humidity control, as well as analyzes the energy-saving effects of centralized central air conditioning systems.

Firstly, the principle of humidity control is based on the process of thermal and moisture treatment of air. Central air conditioning systems generally use cooling, dehumidification, and other methods for humidity regulation. After passing through the cooling coil, the temperature of the air decreases, and the water in the air condenses into water droplets, thus achieving reduced humidity. In addition, by adjusting the temperature of the reheat coil, the humidity and temperature during the air supply process can be further controlled, thereby meeting the indoor environmental comfort requirements<sup>[4]</sup>.

Based on this, there are many humidity control methods, mainly including but not limited to fixed humidity control, variable humidity control, and intelligent humidity management based on predictive control. Fixed humidity control is generally applied in places where stable humidity is required, while variable humidity control can automatically adjust the humidity setpoint according to changes in indoor and outdoor environments to achieve a higher energy efficiency ratio. Intelligent humidity management systems utilize cutting-edge sensor technology and control algorithms to monitor environmental parameters inside and outside the room in real time, predict humidity trends, and adjust humidity control strategies based on these data to achieve optimal energy-saving effects<sup>[5]</sup>. As shown by the results of scholars such as Fang Xing, key energy-saving technologies for high-efficiency refrigeration rooms can ensure that the annual cumulative coefficient of performance of the refrigeration room reaches 6.04. Compared to traditional refrigeration rooms, the total energy consumption of high-efficiency refrigeration rooms is reduced by 38.2%, and the annual carbon emissions can be reduced by 1,224 tons<sup>[6]</sup>.

During the implementation of humidity control strategies, it is necessary to comprehensively consider various factors such as the temperature difference between indoors and outdoors, air humidity, and system load to ensure efficient system operation. Additionally, optimizing humidity control strategies is of crucial importance for enhancing energy-saving effects. By adjusting and optimizing control parameters, such as setting humidity values and reheating temperatures, we can further enhance the energy efficiency of the system, thereby achieving the goals of energy conservation and emission reduction.

#### **3.2. Evaluation indicators for energy-saving effect**

When studying the energy-saving issues of centralized air conditioning systems, it is crucial to evaluate the energy-saving effectiveness of humidity control strategies. Evaluating energy-saving effectiveness involves both system energy efficiency ratio and considerations of environmental comfort and long-term operating costs. This

section discusses and defines a series of evaluation indicators to measure the energy-saving effectiveness achieved by humidity control strategies in practice.

Firstly, it should be considered that the Energy Efficiency Ratio (EER) is a basic indicator for measuring the energy-saving performance of air conditioning systems. It reflects the amount of cooling (or heating) provided by the air conditioning system per unit of energy consumption. Optimizing the humidity level under a humidity control strategy can reduce system energy consumption and improve the EER.

Furthermore, system energy consumption has become a key indicator directly related to operating costs. Adopting a humidity control strategy can reduce the increased workload of the air conditioning system to maintain the set humidity, thereby achieving the goal of reducing energy consumption.

In addition, indoor environmental comfort is also an important aspect of evaluation. Humidity control not only affects air conditioning energy consumption but also directly impacts users' thermal comfort perception. Correspondingly, indoor relative humidity, temperature stability, and air circulation have also become essential components of the evaluation system.

In the evaluation, long-term operational costs are also a crucial factor to consider, encompassing equipment depreciation, maintenance expenses, and energy consumption costs. Implementing efficient humidity control strategies can extend the lifespan of the device and reduce the frequency of maintenance, thereby lowering long-term operational costs.

Broadly speaking, environmental impact is a crucial dimension in evaluating energy-saving effectiveness. Humidity control strategies should consider environmental friendliness during implementation, primarily by reducing greenhouse gas emissions and enhancing sustainable energy utilization.

To evaluate the energy-saving effectiveness of humidity control strategies for centralized air conditioning systems, several indicators need to be considered, including energy efficiency ratio, system energy consumption, indoor environmental comfort, long-term operating costs, and environmental impact. Quantitative analysis of these indicators can provide a comprehensive evaluation of the actual energy-saving effectiveness of humidity control strategies, providing a scientific basis for subsequent strategy optimization<sup>[7]</sup>.

## **4. Research on the optimization and application of humidity control strategies**

### **4.1. Direction of strategy optimization**

When a centralized air conditioning system operates, humidity control is the most significant factor affecting the system's energy consumption. To achieve high efficiency and energy saving, it is necessary to optimize the humidity control strategy. This section will discuss the directions for optimizing the humidity control strategy to reduce energy consumption and improve system performance. Firstly, the optimization of the humidity control strategy should be based on a profound understanding of the system's working principle. By analyzing the system's working principle, key factors affecting humidity control efficiency can be identified, and corresponding improvement measures can be proposed. For example, improving the design of the air handling unit can enhance dehumidification efficiency, thereby reducing system energy consumption.

Secondly, when optimizing humidity control strategies, it is necessary to consider evaluation indicators for energy-saving effects. These include, but are not limited to, system energy consumption, dehumidification efficiency, and indoor comfort. A comprehensive evaluation of these indicators can identify deficiencies in current humidity control strategies and formulate optimization plans accordingly.



In addition, the optimization of humidity control strategies should also be analyzed in conjunction with practical application cases. For example, the fuzzy control model proposed by Zhang Wei and other scholars<sup>[8]</sup> achieves dynamic adjustment of humidity setpoints by coupling multiple variables such as indoor and outdoor temperature and humidity, and personnel density. It has been verified through actual measurements to reduce dehumidification energy consumption by 18–22%, providing a new algorithmic path for strategy optimization. Through research on humidity control practices in centralized central air conditioning systems in different building types, we can summarize efficient strategy optimization methods and provide valuable references for other similar systems in humidity control.

## 4.2. Analysis of practical application cases

When conducting research on humidity control strategies for centralized central air conditioning systems, analyzing practical application cases is a crucial step in verifying the effectiveness of theories. By analyzing different environmental humidity control strategies, we can more accurately evaluate their promotional effects on energy efficiency. The following analysis of some typical examples aims to demonstrate the energy-saving potential of humidity control strategies and their achievements in practice.

### Case 1: Commercial shopping center

As a place with a large flow of people, commercial shopping centers have higher requirements for indoor environmental comfort. Advanced humidity control technologies such as variable frequency control and intelligent sensors can achieve precise humidity regulation<sup>[9]</sup>. Through in-depth analysis of the case, we found that by optimizing humidity control, the energy consumption of this shopping center was reduced by about 15% compared to traditional systems, while also enhancing customer comfort.

### Case 2: Office building

Office buildings generally have large spaces and low personnel density, indicating that their humidity control needs differ from those of commercial shopping centers. By optimizing humidity control strategies for office buildings, such as implementing zoning control and scheduled adjustments, effective energy consumption reduction can be achieved<sup>[10]</sup>. According to feedback from practical applications, the optimized system not only ensures indoor comfort but also successfully reduces energy consumption by approximately 20%.

### Case 3: Hospital environment

As a unique medical environment, hospitals have stricter standards for indoor humidity management to ensure the health of patients and medical staff. By implementing humidity control strategies, such as using efficient dehumidification equipment and accurate humidity monitoring systems, hospitals can achieve better indoor environmental control effects. Through case studies, we have found that this humidity management method not only significantly improves the indoor environmental quality but also helps reduce energy consumption, with energy-saving effects exceeding 10%.

By summarizing all viewpoints and analyzing practical application cases, it can be seen that humidity control strategies can achieve significant energy-saving effects for different types of centralized air conditioning systems. These examples not only demonstrate the theoretical feasibility but also provide valuable practical experience for optimizing humidity control strategies in the future. Future research can further explore different environmental humidity control strategies, with the aim of achieving higher energy efficiency and better indoor environmental quality.

## 5. Conclusion

This paper conducts an in-depth exploration of the humidity control strategy and its energy-saving effect in centralized central air conditioning systems. By analyzing the system's working principle, the importance of humidity control for enhancing the energy efficiency of air conditioning systems is understood. This paper further discusses the principles and methods of humidity control, establishes an evaluation index system for energy-saving effects, and aims to lay a theoretical foundation and provide practical guidance for subsequent research.

Regarding the optimization and application of humidity control strategies, we present the direction of strategy optimization and demonstrate the effectiveness of optimized strategies in practice through actual case analysis. Through the aforementioned research, we believe that centralized central air conditioning systems have great potential for energy saving in humidity control, and propose new perspectives and solutions for the field of building energy efficiency.

Humidity control has a significant impact on centralized air conditioning systems. A reasonable humidity control strategy can both enhance system energy efficiency and reduce energy consumption, which is crucial for achieving green buildings and sustainable development. In future research, we have the opportunity to delve into the synergistic optimization between humidity control and other control parameters, as well as the adaptability under various climatic conditions, with the aim of achieving higher levels of energy-saving benefits. At the same time, with the increasing development of intelligent technology, the application of intelligent and automated control strategies in humidity control will also become an important research direction in the future.

## Disclosure statement

The author declares no conflict of interest.

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