Study on energy saving of air conditioning frequency conversion and speed regulation in public buildings in hot summer and warm winter areas

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Abstract: In order to meet the comfort and environmental protection and energy saving requirements of residential buildings, this paper puts forward a research method for energy saving of air conditioning in public buildings in hot summer and warm winter areas. According to the characteristics of hot winter and warm winter climate and energy consumption of large shopping malls, it analyzes several energy saving modes of air conditioning in large public buildings, simulates and analyzes the energy consumption of air conditioning in residential buildings under different room temperature conditions, optimizes the algorithm of air conditioning frequency conversion energy consumption in public buildings in hot summer and warm winter areas, and standardizes the evaluation mode of air conditioning frequency conversion energy consumption in public buildings. And put forward relevant optimization suggestions. Finally, the experimental results show that the energy-saving effect of air conditioning frequency conversion speed regulation in public buildings in hot summer and warm winter areas is very obvious, and it is worth popularizing.

1. Introduction
The climate of hot summer and warm winter is mostly subtropical humid monsoon climate, warm and humid. In this area, the annual cooling time is long, the air conditioning load is large, and the energy consumption and discharge of air conditioning are large. At present, the energy-saving research of central air-conditioning mainly focuses on the energy-saving control of cooling tower fan, water pump, cold pump, coil fan and traction air-conditioning device. Water chiller is the most energy consuming equipment in central air conditioning. Air conditioning adopts automatic flow and flow control method. It can realize energy saving by adjusting the cooling air volume and water flow of air conditioning cold storage chamber, and can dynamically track the change of air conditioning terminal cooling load.

2. Energy saving of variable frequency speed regulation for air conditioning in public buildings
2.1. Frequency conversion energy consumption algorithm of air conditioning in public buildings in hot summer and warm winter areas
The total heat recovery efficiency of the fresh air heat recovery device is measured:

$$\varepsilon = \frac{m_i (h_i - h_t)}{m_{\text{min}} (h_i - h_t)}$$

Among them: $m_i$ is fresh air volume, kg/S; $m_{\text{min}}$ is the smaller air volume in fresh air and exhaust air, kg/S; $h_1$, $h_2$, $h_3$ is pretreatment fresh air, kJ/kg. Assuming that the fresh air volume is equal to the
exhaust air volume, the formula can be simplified as follows:

\[ e_i' = \frac{(h - h_2)(M - N)}{\delta_{h}(h - h_1)} \]  \hspace{1cm} (2)

In the above algorithm, \( M \) represents the variable frequency fresh air volume of public building air conditioning, and the unit is kg/S; \( \delta \) is the hourly length of air conditioning frequency conversion in public building, and \( N \) is the operation time of variable frequency air conditioning in public building. According to the total air method with the lowest fresh air rate, the following formula is used to calculate the cooling capacity of surface cooler:

\[ \Delta Q = \| e_i' - e_i \| / m_i h_i + m_i h_x - m_s h_s \]  \hspace{1cm} (3)

Where \( m_1 \) is the variable frequency return air volume of public building air conditioner in kg/S, \( m_3 \) is the enthalpy of variable frequency fresh air for air conditioning in public buildings, in kg/S and \( h_x \) is the enthalpy of fresh air of air conditioning frequency conversion in public buildings, in kJ/kg. \( h_1 \) is the variable frequency air supply enthalpy of air conditioning in public buildings, in kg/S. \( h_s \) is the variable frequency return air enthalpy of air conditioning in public buildings, and the unit is kJ/kg. Assuming that the variable frequency fresh air speed of air conditioning in public buildings is 15%, the above algorithm is optimized, and the formula is as follows:

\[ Q = 1/0.85 m_i h_i + 0.15 m_s h_x - m_s h_s \]  \hspace{1cm} (4)

This gives the coil cooling capacity:

\[ Q' = \| e_i' - e_i \| / \sum_{i=1}^{s} Q - \Delta Q \| (m_i h_i + m_i h_x) \]  \hspace{1cm} (5)

When \( h_x \geq h_s \), the accumulated energy consumption of fresh air cooling method is as follows:

\[ Q_{s_{\text{max}}} = 0.85 Q s m_i \sum_{j=1}^{n} [h_j - h_x (i_j)] \sum_{i=1}^{m} \]  \hspace{1cm} (6)

For the fresh air cooling method with \( h_x < h_s \), the cumulative energy consumption is as follows:

\[ Q_{s_{\text{min}}} = Q s m_i \sum_{x=1}^{s} [0.85 h_r + 0.15 h_x (i_2) - h_s (i_2)] \sum_{i=1}^{n} \]  \hspace{1cm} (7)

Where \( m_i \) is the total air intake of the air method, and \( n \) is the length of each working hour of the air method.

2.2. Energy consumption evaluation model of variable frequency air conditioning in public buildings

The energy-saving potential algorithm of the exterior wall of public buildings is as follows:

\[ Q_{W,R} = Q_{s_{\text{max}}} - Q_{s_{\text{min}}} \]  \hspace{1cm} (8)

\[ Q_{W,C} = \frac{\Delta Q}{e_i + 2e_i'} \]  \hspace{1cm} (9)

The evaluation sets of primary, secondary and tertiary indicators of energy consumption of indoor air conditioning in public buildings are as follows:

\[ U_{ij} = \{ u_{\text{energy}}, u_{\text{consumption}}, u_{\text{effect}} \} \]  \hspace{1cm} (10)

\[ U_1 = \{ u_{\text{energy consumption}}, u_{\text{energy type}}, u_{\text{energy recovery}}, u_{\text{energy consumption ratio}} \} \]  \hspace{1cm} (11)

The three-level evaluation index set of variable frequency energy consumption of indoor air conditioning in public buildings is:

\[ U_2 = \{ u_{\text{Energy consumption value}}, u_{\text{Rate of recovery}}, u_{\text{Utilization rate}}, u_{\text{Substitution rate}} \} \]  \hspace{1cm} (12)

Furthermore, each row of indexes in the judgment matrix is multiplied, and the eigenvector can be obtained by n-th power.
The vector $w$ is normalized to obtain the following results

$$w_i = \frac{w}{\sum_{i=1}^{n} w_i}, i = 1, 2, 3, ..., n \quad (14)$$

The weight set of energy consumption evaluation index is further calculated

$$w = w_n, w_m, n = 1, 2, 3, \quad m = 1, 2, 3, 4 \quad (15)$$

The specific algorithm to determine the maximum energy consumption of the matrix is as follows:

$$\psi_{\text{max}} = \frac{1}{n} \sum_{i=1}^{n} \Delta w_i, i = 1, 2, 3, ..., n \quad (16)$$

The judgment method of the maximum eigenvalue of the judgment matrix is as follows:

$$CI = \left(\psi_{\text{max}} - n\right)/(n - 1) \quad (17)$$

$$CR = CI / RI \quad (18)$$

2.3. Realization of energy saving by frequency conversion and speed regulation of air conditioning in public buildings

Air conditioners are divided into three types of energy consumption (cold and heat source method, water supply method and gas supply method). The energy consumption is mainly affected by design factors and operation management factors. Based on this, the processing frame of frequency conversion and speed regulation of air conditioning in public buildings is optimized, as shown in the following figure:

Fig. 1 Processing frame of frequency conversion and speed regulation of air conditioning in public buildings
u is the evaluation index, which is recorded as \( Z_{ij} \) according to the possible degree of P evaluation scale, i.e. the degree of subordination. Each member vector has the following subset:

\[
Z_i = (z_{i1}, z_{i2}, z_{i3}), i = 1, 2, 3 \tag{19}
\]

Therefore, the membership matrix of frequency conversion feature management is established as follows:

\[
Z = \begin{bmatrix}
z_1 \\
z_2 \\
z_3 \\
\end{bmatrix} = \begin{bmatrix}
z_{11}, & z_{12}, & z_{13} \\
z_{21}, & z_{22}, & z_{23} \\
z_{31}, & z_{32}, & z_{33} \\
\end{bmatrix} \tag{20}
\]

Based on index weight \( W_i \) and membership matrix \( Z \), the environmental performance of variable frequency speed regulation in public buildings is comprehensively evaluated.

\[
F = W_i W_{\text{max}} \cdot Z = (w_1, w_2, \ldots, w_i) \begin{bmatrix}
z_{11}, & z_{12}, & z_{13} \\
z_{21}, & z_{22}, & z_{23} \\
z_{31}, & z_{32}, & z_{33} \\
\end{bmatrix} = (f_1, f_2, \ldots, f_i) \tag{21}
\]

the comprehensive evaluation vector of environmental protection performance of building air conditioning frequency conversion is standardized.

\[
\xi = F \cdot Z = (f_1, f_2, f_3) \begin{bmatrix}
z_1 \\
z_2 \\
z_3 \\
\end{bmatrix} \tag{22}
\]

According to the above steps, a comprehensive evaluation model of environmental protection performance can be established.

![Diagram](Fig. 2 Energy saving processing steps of variable frequency equipment)

3. Analysis of experimental results

Air conditioning chillers with high performance parameters are selected for the project: three centrifugal chillers with 1970 kW (560 RT) and one screw chiller, whose performance parameters meet the standard requirements.

| Table 1 refrigeration performance parameters of variable frequency speed regulation water chiller |
|-------|--------|----------|----------------|----------------|
| number | Equipment type | Rated cooling capacity (kw) | Actual performance parameter equipment | Standard requirements |
|-------|--------|----------|----------------|----------------|

4
The power consumption per unit air volume of fan in ventilation and air conditioning method is as follows:

| Equipment type                  | Equipment number | Power consumption per unit air volume |
|---------------------------------|------------------|---------------------------------------|
| Box type centrifugal fan        | PFY-(2)-2        | 0.25-0.32                             |
| Box type centrifugal fan        | PF-(1)-6         | 0.20-0.27                             |
| Combined air handling unit      | JK-(1)-23        | 0.13-0.20                             |
| Combined air handling unit      | JK-(1)-12        | 0.17-0.25                             |

In the case of no heating or air conditioning equipment, the energy consumption can be expressed as follows:

\[ t_\gamma(r) = \int_{-\infty}^{\infty} \sum_{j=1}^{m} \sum_{l=1}^{n} r \varepsilon_j e^{j(1-\gamma)} q_j(\eta) d\eta \]  

Among them, \( e \) is indoor room temperature, \( q_j \) is various influencing factors of outdoor energy consumption, \( \lambda \) is the eigenvalue of indoor space in state space method, \( d \) is the eigenvalue of indoor space, \( \eta \) is the outdoor temperature, solar radiation and other influencing factors. Based on the analysis of dynamic error curve, the error analysis accuracy of the two methods is compared. The results are shown in the figure.

![Accuracy of analysis results](image)

Based on the above detection results, compared with the traditional method, the energy-saving method of building air-conditioning frequency conversion speed regulation under the guidance of this method is obviously better in the actual application process.

### 4. Conclusion

At present, the density of high-rise buildings is too high, the energy consumption of air conditioning is low, and the awareness of energy-saving in the whole society has not been generally improved, which restricts the development of energy-saving work. From the point of view of energy saving, because indoor air-conditioning cannot fully meet the needs of people, this paper puts forward the research method of variable frequency speed regulation for public buildings in hot summer and warm winter.
areas. Reduce energy consumption and facilitate the simplification of management procedures.

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