THERMAL ENERGY CONSTANT TEMPERATURE CONTROL SYSTEM OF BUILDING ENERGY SYSTEM BASED ON DYNAMIC ANALYSIS METHOD

by

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If the intelligent building's indoor environment's constant temperature is accurately controlled, the comfort of the building can be improved. When we perform constant temperature control, there will be large fluctuations in the supply air temperature, which results in the traditional methods that cannot control the temperature within a reasonable range. Therefore, the paper proposes an optimal control method for the indoor environment constant temperature of intelligent buildings. In the IoT environment, we integrate the multi-agent technology to design the temperature fuzzy control structure, determine the input and output variables of the intelligent building temperature control system and its fuzzy set, use the dynamic analysis method to modify the fuzzy rules, and integrate it with bilinear The control algorithm builds a dynamic temperature control model for intelligent buildings to maintain the indoor temperature at the set value when the supply air temperature fluctuates significantly. This method makes up for the shortcomings that the current system cannot adapt to the intelligent building environment changes. The simulation results show that compared with the traditional algorithm, the improved algorithm can significantly improve the robustness of the intelligent building constant temperature control, and the temperature control stability is vital.

Key words: *dynamic analysis method, IoT, intelligent building, thermal energy, constant temperature control*

Introduction

With the continuous improvement of global informatizationday, intelligent buildings have entered people's daily lives. Most smart buildings use the IoT technology to intelligently connect the office, temperature control, and TV system engineering of the building, and the wireless control system forms a more extensive measurement and control network. In this context, how to effectively improve the current intelligent building constant temperature control system has become a significant problem in related fields. The intelligent building constant temperature control optimization method based on the IoT can maintain the indoor temperature at the set value under the condition of large fluctuations in the supply air temperature, which makes up for the shortcomings of the current system that cannot adapt to the changes in the intelligent building environment, and has significant economic benefits. Value and application value.

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The paper proposes an optimal control method for the indoor environment's constant temperature based on the BP network and dynamic analysis method. This method first defines the temperature of the monitoring area as an optimization problem. It uses a forward neural network to define the temperature field identification calculation structure and completes the intelligent building's temperature control. This method is relatively simple but has the problem of unstable control performance. The paper adopts a D51260-based intelligent building indoor environment constant temperature optimization control method. This method first obtains the number of pulses of the temperature coefficient oscillator to control the low temperature coefficient oscillator, calculates the digital output of the measured temperature, and builds the main flow structure the temperature control extension. Based on this, the intelligent building temperature control method is completed. This method has strong control stability, but the intelligent building constant temperature control system's current control parameters are fixed and cannot adapt to changes in the intelligent building environment. We propose an intelligent building indoor environment constant temperature optimization control method based on the dynamic analysis and neural network PID controller [1]. This method introduces the advantages of the genetic algorithm's global optimal solution the PID controller, establishes a temperature dynamic control model of the PID controller based on the neural network, and uses the model to complete the temperature control of the intelligent building. This method has a high precision for indoor environment constant temperature control of intelligent buildings, but it has certain limitations. We propose an optimal control method based on intelligent building indoor environment constant temperature. The simulation results show that compared with the traditional algorithm, the proposed algorithm can significantly improve the robustness of intelligent building constant temperature control, and the temperature control stability is vital.

Explanation of related concepts

Building energy efficiency involves many aspects, including wall insulation, airtightness of doors and windows, heating system efficiency, and shading system. Among them, the heating system's indoor constant temperature control investment is relatively small, and the energy-saving potential is enormous. The heating radiator temperature is too high or too low due to the system's hydraulic imbalance and the lack of indoor temperature control measures. Radiator thermostatic control valve plus a balance valve is a solution this problem. The balance valve is installed on the vertical riser of each unit to ensure the hydraulic balance of each unit in the building. The thermostatic valve further controls the indoor temperature through each set of radiators, which balances the heat distribution and avoids overheating or overcooling causes additional energy waste, thereby significantly reducing heating energy consumption [2]. The thermostatic valve mainly sends a signal through a sensor that can sense changes in ambient temperature at any time and adjusts the flow of hot water in real-time accordingly to keep the room temperature constant at a set level. It can sense various forms of free heat, such as the heat emitted by the human body, household appliances, and sunlight. This shows that if people cause 30% heat loss due to opening windows, thermostatic valves' energy-saving potential in heating systems can be as high as 30%. According to the statistical results of heat metering pilot projects such as Tianjin Kaili Garden, thermostatic valves and differential pressure controllers will significantly reduce the overall energy consumption compared to similar houses with equivalent wall insulation. The wall insulation of Kaili Garden is designed according to the one-step energy-saving standard. In 2001-2003, the average heat consumption during the heating season was 24.33 W/m^2. Danfoss' pilot projects in Eastern European countries such as Poland also show that without any improvement in wall insulation, the installation of thermostatic valves alone can save energy by 15-30%.

In the *Opinions on Further Promoting the Reform of the Urban Heating System* issued by the Ministry of Construction and the other eight ministries on December 6, 2005, all regions are required to complete the reform of commercialization and monetization of heating within two years in principle. Buildings must be equipped with thermostatic radiator valves, and new houses must also be equipped with household heat metering conditions. As the best solution for indoor thermostatic control, the combination of thermostatic valve and differential pressure controller has the following advantages:

- Use free heat to save energy.
- Keep the indoor temperature constant at the required level to improve indoor comfort.
- Ensure the hydraulic balance of the system and improve the overall operating efficiency of the system.

Under the EPBD regulations guidance, the European Energy Conservation Association (ACE) recently issued a report. The report studies the potential of energy-saving renovation projects for high rise residential buildings (high rise refers to buildings with five floors or more, and most residential buildings in my country can be classified as such) and analyzes the efficiency of investment in energy-saving renovation projects in this type of residential building renovation process, and found that compared with other energy-saving renovation measures, the investment cost for thermostatic valves is relatively low. At the same time, the rate of return is close to the highest. Based on European countries' data, the average pay-back period of investment in thermostatic valves is about one year, which is one of the fastest returns of all retrofit projects. The pay-back period of investment in wall insulation is, on average, five times that of thermostatic valves.

First of all, the local government should undoubtedly formulate or modify the local building design standards and acceptance specifications gradually following the eight ministries and commissions requirements and make mandatory regulations for the indoor temperature control of the heating system. This is the most effective and the most effective way to ensure energy-saving heating. Besides, in other auxiliary measures, we can also learn from relevant European energy regulations. For example, EPBD has a provision that *a building must have a building energy-saving performance permit during the process of construction, sale or lease*. According to this regulation, some special energy-saving measures, such as the installation of thermostatic valves, may be linked to the energy-saving performance certificate level to obtain corresponding financial subsidies. Besides, the European Union's Energy Terminal Efficiency and Energy Service Regulations (ESD), which is under review in Europe, stipulates that member states must abolish or modify their national laws and regulations that hinder or restrict the financing of energy-saving measures in the energy service market. Encourage the establishment of public energy conservation funds through various channels and forms. This provision will enable all member states to repeal laws that impede investment in improving energy efficiency and encourage multi-channel financial support for energy-saving construction or renovation of buildings. If my country can implement and apply similar laws, it will also obtain multi-channel and multi-form renovation or construction funds to ensure the implementation of cost-effective building energy-saving measures. As one of the most urgent energy-saving measures, thermostatic valves' installation will undoubtedly encounter financial difficulties in the implementation process. Therefore, government subsidies and preferential policies will promote the smooth implementation of the eight ministries' documents.

Principles of temperature control in the indoor environment of intelligent buildings

In the process of temperature control of intelligent buildings, we use the detection compressor's speed to obtain the temperature value generated by the control system unit through calculation. The error between the temperature value generated by the unit and the required temperature value is generated by a controller to generate a given frequency signal, and the inverter generates a pulse control signal according to the given frequency to control the speed of the compressor so that the temperature generated by the unit reaches the actual temperature demand. The specific steps are detailed

Assuming that F_a is the space to be controlled, P_i – the function of the space position, $m(i, t)$ – the transfer function of the temperature control system, and M – the speed of the compressor, then use eq. (1) to obtain the temperature value generated by the control system unit:

$$\Phi(z) = \frac{F_a \otimes P_i}{m(i,t)M} \times n(k,l) \tag{1}$$

where $n(k, l)$ is the temperature value given by the control system. Assuming that $g(m, n)$ represents the time constant, km is the expected closed-loop response, and $\beta\|k\|$ the deviation between the given value and the actual output value $b(j, k)$, then use eq. (2) to force the error between the temperature value generated by the unit and the required temperature value to pass a the controller generates a given frequency signal:

$$\omega(t) = \frac{km \times \beta\|k\|}{g(m,n)} \frac{b(j,k)\theta(u)}{\overline{\omega}(it)} \tag{2}$$

where $\theta(u)$ is the closed-loop transfer function of the system and $\overline{\omega}(it)$ – the control law of control. Suppose that $r(i)$ represents the frequency given by the frequency converter at the time i, then use eq. (3) to make the temperature generated by the unit reach the actual temperature demand:

$$m(\theta, \overline{\omega}) = \frac{\Phi(z)}{\omega(t)} \times \beta(k,m) C_{(s)} \tag{3}$$

where $\beta(k, m)$ is the real-time change of temperature load Dong and $C(s)$ is the dynamic process of the closed-loop. To sum up, it can be explained that the principle of intelligent building constant temperature control is used to complete the constant temperature control of the intelligent building. When performing constant temperature control, the supply air temperature will fluctuate greatly, resulting in the traditional method, not controlling the temperature within a reasonable range [3]. An intelligent building indoor environment constant temperature optimization control method is proposed.

Optimal control of indoor environment constant temperature for smart buildings based on the IoT

Formation of thermostatic control rules

In the process of optimizing the constant temperature control of the intelligent building of the IoT, the temperature fuzzy control structure is designed with multi-agent technology, the input and output variables and the fuzzy set of the intelligent building temperature control system are determined, and the fuzzy rules are modified by the dynamic analysis method.

Suppose that $X = \{x_1, x_2. x_3\}$ is the input vector of the constant temperature control state, $x_1, x_2. x_3$ represents the temperature difference and its rate of change, the output frequency change of the temperature control compressor, R_L is the constant temperature control rule database, r is the return value of the temperature control, and r_i is the constant temperature adjustment the action of, needs to meet the condition of $r_i = 2$, then use eq. (4) to calculate the total return value of each period of inference under the agent:

$$r = \frac{R_L r_l}{X = \{x_1, x_2, x_3\}} \tag{4}$$

Use the reasoning agent to observe the current temperature control environment information and calculate the actual value of each fuzzy rule:

$$\mu_j(X) = \mu_j^1(x_1) \times \mu_j^2(x_2) \times \mu_j^3(x_3) \tag{5}$$

where satisfy the condition of $j = 1, 2, 3... 49$ and $\mu_{ij}(x)$ represents the membership function of the state input variable. Suppose that $(f_1, f_2 ... f_7)$ is the characteristic point of the compressor operating frequency change parameter and $(w_{j1}, w_{j2} ... w_{j7})$ is the weight of each characteristic point [4]. According to the experience of constant temperature regulation, the total weight of each characteristic point is calculated:

$$W_k = \frac{\sum_{j=1}^{49} w_{jk} \bullet \mu_j(X)}{\sum_{j=1}^{49} \mu_j(X)} \tag{6}$$

where w_{jk} is the feature vector corresponding to each feature point. Suppose that a^t represents the control action selected by the agent at time t, which causes the state to change from x^t to y^t. According to the return of this action, use eq. (7) to modify the fuzzy rule to obtain the new feature point weight:

$$w_{jk} = \frac{(1 - a^t)}{(x^t, y^t)} W_{\text{man}} \bullet \gamma \tag{7}$$

wherw γ is the discount rate and W_{man} – the maximum value in W_k. To sum up, it can be explained that in the process of optimizing the constant temperature control of the intelligent building of the IoT, the temperature fuzzy control structure is integrated with the multi-agent technology to determine the input and output variables of the intelligent building temperature control system and its fuzzy set, and use dynamic The analysis method modifies the fuzzy rules, which provides a basis for realizing the optimal control of the constant temperature of intelligent buildings in the IoT.

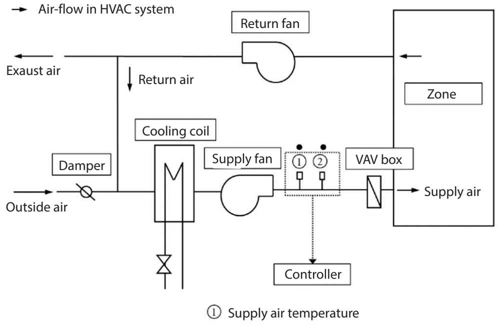

Figure 1. Variable air volume temperature regulation system

Realization of constant temperature optimization control based on bilinear control

In optimizing the constant temperature control of the smart building of the IoT, it is assumed that θ is the current smart building temperature, t – the time, D – the frequency converter, and T – the temperature sensor. The principle of the variable air volume temperature control system is shown in fig. 1. When the external interference state is large, the temperature of the constant temperature will fluctuate wildly. As shown in fig. 2, at this time, the air supply is controlled by adjusting the air supply operating frequency, and the indoor temperature controller is defined as a bilinear feedback controller [5]. According to the characteristic point weights of the new compressor operating frequency change parameters obtained in section *Formation of thermostatic control rules*, the fan operating frequency is calculated using the bilinear control algorithm. The control equipment is sent to the fan to complete the constant temperature optimization control.

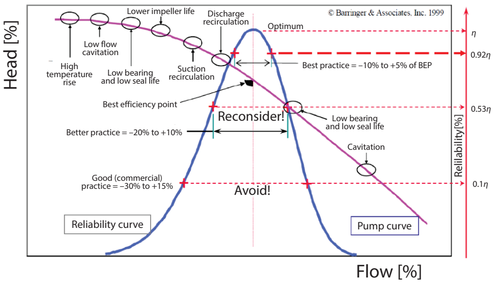

Figure 2. Frequent start and stop temperature changes of heat pump units

Assuming that θ_z is the smart indoor temperature and θ is the output temperature, the weights of the characteristic points of the new compressor operating frequency change parameters represented by w_{jk} obtained in section *Formation of thermostatic control rules* are used as the basis, and the temperature of the smart building is given by change dynamic model:

$$C_z \frac{\mathrm{d}\theta_z}{\mathrm{d}t} = c_a p_a \upsilon_s (\theta_s - \theta_z) + \frac{q_z}{w_{jk}} \tag{8}$$

where c_a is the specific heat capacity of the air, p_a – the air density, and υ_s – the air volume of the supply air. Use eq. (8) to calculate υ_s:

$$\upsilon_s = C_z \frac{\mathrm{d}\theta_z}{\mathrm{d}t}(a_1 f_1) + (a_0) \tag{9}$$

where a_1 is the correction factor, f_1 – the rated frequency of the fan, and a_0 – the frequency weight. Assuming that $e_{z,k}$ is the tracking error at time k, h_1 is the sampling interval, and k represents the current time, then the output constant temperature control value can be expressed:

$$\upsilon_{s,k} = \frac{(1-\gamma)e_{z,k}}{\hat{\xi}_{z,k} \bullet k} \times \gamma \oplus e_k \oplus h_1 \tag{10}$$

where $\hat{\xi}_{z,k}$ is the estimated cooling load at time K and γ – the custom parameter [6]. The cooling load is a real-time changing quantity. Assuming that $1 - \lambda$ is the forgetting factor, use eq. (11) to estimate the cooling load of the smart building:

$$\hat{\xi}_{z,k} = \lambda \hat{\xi}_{z,k-1} + (1-\lambda)\hat{\xi}_{z,k}\upsilon_{s,k} \tag{11}$$

where $\hat{\xi}_{z,k-1}$ is the cooling load at time $k - 1$, $\hat{\xi}_{z,k}$ – the cooling load at time K, and υ_{sk} – the constant temperature control quantity at time K. The previous method can explain that the intelligent building constant temperature optimization control method based on the IoT can effectively complete the optimization of the intelligent building constant temperature control by using this method [7].

Simulation results and analysis

To prove the optimal method of constant temperature control for intelligent buildings based on the IoT, an experiment is needed. Build a building stable temperature control simulation platform under the MATLAB software environment [8]. Taking the temperature setting value of the intelligent building thermostat control as a parameter, the air supply temperature is not controlled, and the heat pump unit is controlled by the switch, and the indoor thermostat control setting value is set to 24 °C.

Comparison of control response curves of different algorithms

Using the algorithm and algorithm in this paper to carry out the experiment of intelligent building constant temperature control, compare the control response curves of the two algorithms under steady-state and different load conditions. The comparison results are shown in figs. 3-5.

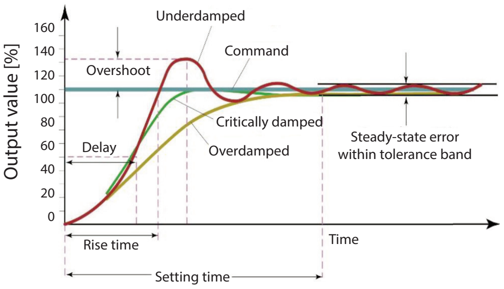

Figure 3. Control response curves of different algorithms in a steady-state

From the analysis in figs. 3-5, it can be concluded that the response effect of using the algorithm of this paper for intelligent building constant temperature control is better than that of the algorithm of [9] for the response effect of intelligent building constant temperature control. This is mainly because the algorithm is used in this paper [10]. When performing optimal control of the constant temperature of an intelligent building, in the environment of the physical network, the temperature fuzzy control structure is integrated with the multi-agent technology to determine the input and output change and the fuzzy set of the intelligent building temperature control system, and use the dynamic analysis method to modify the fuzzy. Based on this rule, it is combined with a bilinear control algorithm to form a dynamic temperature control model of intelligent building, thus ensuring the effectiveness of the algorithm in this paper for intelligent building constant temperature control.

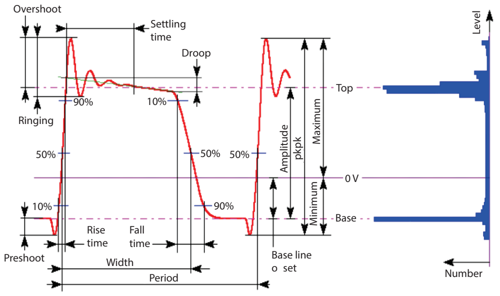

Figure 4. Comparison of control response curves of different algorithms when the load is small

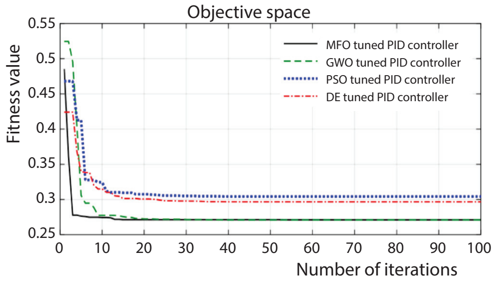

Figure 5. Comparison of control response curves of different algorithms when the load is large

Comparison of control stability of different algorithms

This paper's algorithm and algorithm are used to carry out the experiment of intelligent building constant temperature control, and the control stability of two different algorithms is compared. The comparison result is shown in fig. 6.

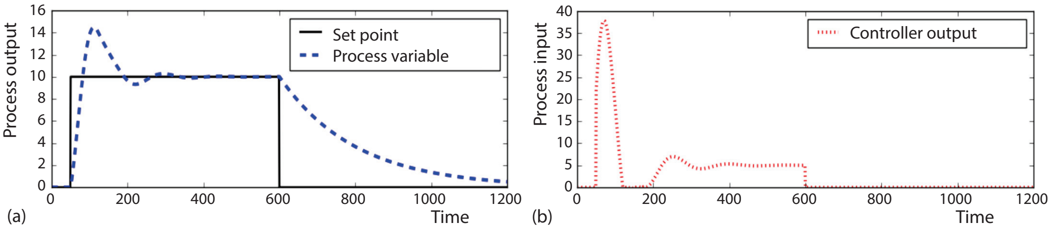

Figure 6. Comparison of stability of temperature control by different algorithms

From the analysis in fig. 6, it can be concluded that the stability of the intelligent building constant temperature control using the algorithm of this paper is better than that of the literature algorithm for the stability of the intelligent building constant temperature control [10]. This is mainly because the algorithm of this paper is used for the intelligent building constant temperature control. Integrating the bilinear control algorithm to form the intelligent building constant temperature dynamic control model, in the case of large fluctuations in the supply air temperature, the indoor temperature is maintained at the set value, which makes up for the shortcomings of the current system that cannot adapt to the changes in the intelligent building environment. To ensure the stability of the algorithm in this paper for intelligent building constant temperature control. The simulation results show that compared with the traditional algorithm, the proposed algorithm can significantly improve the robustness of intelligent building constant temperature control, and the temperature control stability is vital.

Conclusion

The control parameters of the current intelligent building constant temperature control system are fixed and cannot adapt to the intelligent building environment's changes. The paper proposes an optimization method for constant temperature control of intelligent buildings based on the IoT. The simulation results show that compared with the traditional algorithm, the paper's algorithm can significantly improve the robustness of intelligent buildings' temperature control, and the temperature control stability is vital.

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