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Research on the Mechanism Model of Environmental Temperature and Humidity Control in Artificial Light Source Plant Factory

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Abstract: There is a strong cross-coupling and time delay between the temperature and humidity in the artificial light source type plant factory, which makes it difficult to control the environmental parameters alone. Therefore, this paper first analyzes the basic composition of the air treatment equipment in the artificial light source type plant factory, combines the temperature mechanism model and the humidity mechanism model, establishes the energy conversion balance equation of the air treatment equipment, and determines the dynamic nonlinear model of the temperature and humidity control system. The model is verified and analyzed, and the accuracy of the model is determined by comparing the output value of the calculation system with the measured value of the steady-state operating point in the actual field, which provides a theoretical basis for the next temperature and humidity control strategy.

1. Introduction

The artificial light source type plant factory has the characteristics of the controllability of the artificial light source in the closed system and the forced circulation of the internal air, so that the control equipment can realize continuous control and adjustment, and its input and output are always in constant pulse changes[1-4]. Temperature and humidity are continuous variables, and their physical laws are continuous dynamics[5-6]; control equipment (such as artificial light sources, air conditioners and other equipment) operates based on logical rules, and its operating rules are expressed as discrete events driven by events, accompanied by with continuous dynamic changes[7-8]. Discrete events and continuous dynamics interact and influence, making the plant factory system a complex hybrid dynamic system[9]. The temperature and humidity environment system of the artificial light source type plant factory is a typical multiple-input multiple-output (MIMO) system. The main factors affecting the temperature and humidity are supply air temperature, supply air volume flow, supply air moisture content, etc., and there are differences between temperature and humidity. Due to strong cross-coupling and time delay, it is difficult to control environmental parameters alone. This paper first analyzes the basic composition of the air treatment equipment in the artificial light source type plant factory, establishes the energy conversion balance equation of the air treatment equipment, determines the dynamic nonlinear model of the temperature and humidity control system, and verifies and analyzes the model, in order to establish the control of the temperature and humidity system. The strategy provides a theoretical basis.

2. Mechanism Model of Temperature and Humidity in Plant Factory

Due to the comprehensive influence of factors such as the internal environment of plant factories, planting structure, control methods, and crop types[10-11], the spatial distribution of temperature in the internal environment in the horizontal and vertical directions is uneven. For the convenience of research, it is considered that energy and mass in the plant factory are conserved, and the distribution of temperature and humidity in the internal space of the environment within the research range is set to be uniform and consistent.

In the plant factory, the light energy required for plant growth is provided by an artificial lighting system; a closed warehouse-like space structure with high thermal insulation is made of opaque thermal insulation materials, which limits the energy exchange between the internal environment and the outside, so that the The heat energy exchange through the structural panels is minimized; the heating and cooling of the internal environment must be through the action of the air conditioner, and the energy entering the internal system of the environment leaves through the forced circulation of the air. Therefore, in the case of fully artificial production and opaque façade, the building structure can be regarded as adiabatic; the plant factory uses only air conditioners for heating and cooling; the soil surface is covered with film or the nutrient hydroponic pond is better sealed, and the soil can be ignored. Or the evaporation of water from the nutrient solution, and the condensation of water vapor mainly occurs in the turn-off stage of the artificial light source, which is small compared with the total amount of crop transpiration and can be ignored. Therefore, a simplified model was developed to illustrate the energy balance of the plant factory, including the energy exchange of sensible and latent heat among the various internal surfaces.

Changes in humidity within a plant factory, that is, changes in the water vapor content of the interior air, are determined by the indoor moisture balance. Moisture changes were related to indoor crop transpiration rates, outdoor humidity and ventilation rates. For the convenience of the study, it is assumed here that the humidity distribution in the greenhouse is uniform. Due to the structure of the plant factory, ground evaporation is very little, so its effect on indoor humidity can be ignored. The temperature mechanism model of plant factory is obtained, as shown in formula (1); the humidity mechanism model of plant factory is obtained as shown in formula (2).

$$\frac{dt_a}{dt}+\left(\frac{k_s \cdot q_s}{V \cdot c_{ap}}-\frac{A_p}{r_a \cdot V}\right)t_a=\frac{k_s \cdot q_s \cdot t_s}{V \cdot c_{ap}}+\frac{\tau \sum_{i=1}^{n} p_i t_W}{\rho_{\mathrm{a}} \cdot V \cdot c_{ap}}+\frac{A_p}{r_a \cdot V}t_p -\frac{A_p \cdot R_n \cdot \left(1-e^{-kLAI}\right)}{\rho_{\mathrm{a}} \cdot V \cdot c_{ap}+\dfrac{\rho_{\mathrm{a}} \cdot V \cdot c_{ap} \cdot \gamma \left(t_p-t_a\right)}{e_0 RH_{in}\left(e^{\frac{17.4t_p}{239+t_p}}-e^{\frac{17.4t_a}{239+t_a}}\right)}} \tag{1}$$

$$\rho_a V \frac{dW_a}{dt} = \frac{\left(1-e^{-KLAI}\right)\cdot R_n}{\rho_a \cdot V \cdot \lambda\left(1+\beta\right)} + \frac{q_s \cdot \left(W_S - W_a\right)}{V} \tag{2}$$

In formulas (1) and (2), λ —the latent heat of evaporation of water, $\mathrm{J/g}$; $\mathrm{kP_a/K}$; LAI —the leaf area index, ($LAI = \frac{A_p}{A}$; A_P is the leaf area, $\mathrm{m^2}$;A is the ground area, $\mathrm{m^2}$); γ —the thermometer constant, $\gamma = 0.0646\mathrm{kPa/^oC}$; r_a —the aerodynamic impedance of the crop leaf boundary layer, s/m; RH_{in} —the internal relative humidity,%. R_n is the total net radiation intensity of the crop canopy, $\mathrm{W/m^2}$; k is the extinction coefficient, dimensionless; β is the Born ratio, dimensionless; γ is the thermometer constant, $\gamma = 0.0646\mathrm{kPa/^oC}$; k_s is the air-conditioning air supply capacity coefficient, $k_s = 1.21\left(\mathrm{kJ/\left(m^3 \cdot {^oC}\right)}\right)$; m_s is the air-conditioning air supply $\mathrm{kg/s}$; q_s is the volume flow, $\mathrm{m^3/h}$; t_s is the air-conditioning supply air temperature, $\mathrm{^oC}$; t_r is the air-conditioning return air temperature, $^\circ C$; m is the air quality in the plant factory, kg ; V is the indoor volume, $\mathrm{m^3}$; ρ_a is the indoor air density, $\mathrm{kg/m^3}$, $\rho_a = 1.199\left(\mathrm{kg/m^3}\right)$; c_{ap} is the specific heat of the air at constant pressure in the plant factory, $\mathrm{kJ/\left(kg \cdot {^oC}\right)}$, $c_{ap} = 1.009\left(\mathrm{kJ/\left(kg \cdot {^oC}\right)}\right)$; t_a is the indoor temperature, $\mathrm{^oC}$; τ —the power factor of the artificial light source, dimensionless; P —the single artificial light source Power, W ; n —the number of artificial light sources; t_W —the running time of artificial light sources, h. W_a is the moisture content of the air inside the plant factory, g/kg ; W_s is the moisture content of the air entering the plant factory (the moisture content of the supply air), g/kg .

3. Composition of Plant Factory Air Treatment Equipment

The air handling equipment system of the plant factory generally includes fresh air grille, fresh air valve, return air valve, air filter, preheater, surface cooler and air supply unit[12]. Through cooling water cycle, chilled water cycle, refrigeration heat cycle[13] and other working processes to realize the temperature and humidity control and regulation in the system, the principle of plant factory air treatment equipment (water cooling), as shown in Figure 1.

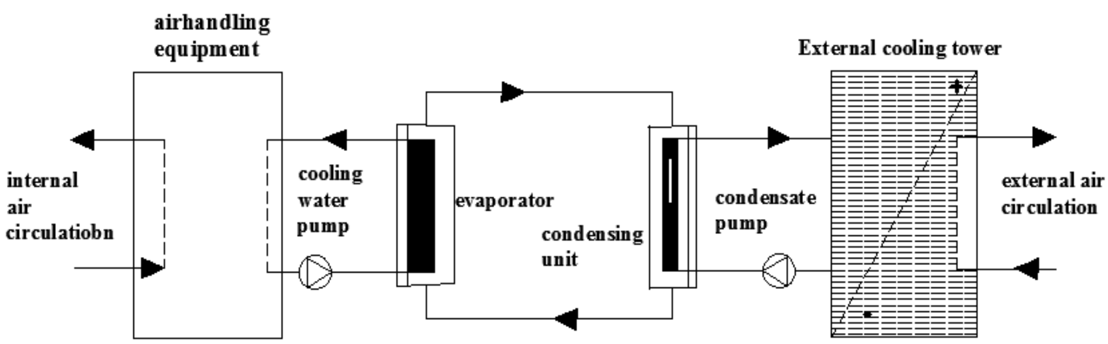

Figure 1 : Schematic diagram of air treatment equipment (water cooling) in plant factory

Air conditioning equipment has the following characteristics:

(1) In terms of air volume control, it is controlled by a variable frequency motor. The air volume of the air handling system is generally a fixed value. The air volume can be adjusted by controlling the opening of the valve, or by adjusting the ratio of fresh air to return air;

(2) In terms of working condition conversion, in summer, it is regulated by the refrigerator, and the air temperature is regulated by controlling the flow of cold water; in winter, it is regulated by the preheater to regulate the air temperature;

(3) In terms of temperature and relative humidity, as environmental parameters, they are controlled internally at the same time. When the moisture content remains unchanged, the temperature and relative humidity are inversely proportional, that is, the temperature increases and the relative humidity decreases.

4. Establishment and Verification of Dynamic Model of Ambient Temperature and Humidity Control

In the air treatment equipment, the air heat exchange in the temperature and humidity environment is realized at the fan coil unit. The cold water flows through the fan coil unit, and the heat is transferred to the heat conduction meson inside the fan coil unit, and then the heat is transferred to the fan coil through the heat conduction meson. On the surface of the pipe, the coil fan passes the fresh air or fresh air and return air through the surface of the coil to realize heat exchange; at the same time, when dehumidification is required, it is also realized in the fan coil. The working principle is shown in Figure 2.

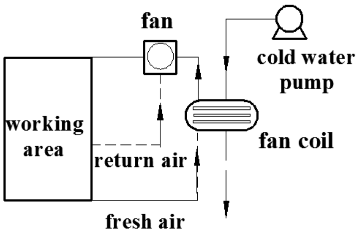

Figure 2: Working principle of plant factory air treatment equipment (fan coil unit)

4.1. Mechanism Model of Temperature and Humidity Control Equipment

Taking the fan coil unit as the research object, without considering the fan coil unit structure, pipeline leakage and structural heat loss, the energy conversion balance equation of the fan coil unit is established[14]:

$$m_w C_f \frac{dt_f}{dt} = q_s C_a \left(t_{s1} - t_s\right) - q_w C_f \left(t_{w2} - t_{w1}\right) \tag{3}$$

$$t_{s1} = \frac{q_x}{q_s} t_x + \frac{q_h}{q_s} t_h \tag{4}$$

In formulas (3) and (4), m_w - the mass of cold water in the fan coil unit, kg; q_w - the flow rate of cold water in the fan coil unit, kg/s; C_a - the specific heat capacity of the air on the wind side of the fan coil unit, KJ/kg ℃; C_f - the specific heat capacity of the fan coil unit , KJ/kg ℃; C_w - Fan coil specific heat capacity of cold water KJ/kg ℃; t_f - Fan coil surface temperature, ℃; t_{s1} - Fan coil inlet air temperature, ℃; t_{w1} -Fan coil inlet water temperature, ℃; t_{w2} -Fan Coil outlet water temperature, ℃; q_x - Fresh air flow, m3/h; q_h -Return air flow, m3/h; t_x - Fresh air temperature, ℃; t_h - Return air temperature, ℃.

Regardless of heat loss, the surface temperature of the fan coil is equal to the supply air temperature, that is $t_f = t_s$, the return air temperature is equal to the temperature in the plant factory, that is $t_h = t_a$.

Substituting equation (4) into (3), get:

$$\frac{m_w C_f}{q_s C_a}\frac{dt_s}{dt} + t_s = \frac{q_x t_x + q_h t_a}{q_s} - \frac{q_w C_f}{q_s C_a}\left(t_{w2} - t_{w1}\right) \tag{5}$$

From the analysis of formula (5), the following conclusions can be drawn:

1) The fan coil unit has the characteristics of strong coupling and time delay due to different structures, lengths, etc. and the interaction of fans. Due to the air supply volume and speed, indoor temperature, different working conditions (summer and winter), and the working time of artificial light sources, the temperature and humidity environment in the plant factory also has the characteristics of strong interference and constant changes.

2)Factors affecting the supply air temperature: volume flow of supply air- q_s , internal temperature- t_a , cold water flow in the fan coil- q_w , cold water temperature difference, fresh air flow- W_r , and fresh air temperature- t_x .

Combined with Equation (1), Equation (2) and Equation (5), a complete nonlinear dynamic model of the temperature and humidity control system is constructed, as shown in Equation (6), and the dynamic characteristics of the temperature and humidity control system in the plant factory are initially obtained.

$$\begin{cases} \dfrac{dt_a}{dt} + \left(\dfrac{k_s \cdot q_s}{V \cdot c_{ap}} - \dfrac{A_p}{r_a \cdot V}\right) t_a = \dfrac{k_s \cdot q_s \cdot t_s}{V \cdot c_{ap}} + \dfrac{\tau \sum_{i=1}^{n} p_i t_W}{\rho_a \cdot V \cdot c_{ap}} + \dfrac{A_p}{r_a \cdot V} t_p \\ \qquad - \dfrac{A_p \cdot R_n \cdot \left(1 - e^{-kLAI}\right)}{\rho_a \cdot V \cdot c_{ap} + \dfrac{\rho_a \cdot V \cdot c_{ap} \cdot \gamma \left(t_p - t_a\right)}{e_0 RH_{in}\left(e^{\frac{17.4 t_p}{239 + t_p}} - e^{\frac{17.4 t_a}{239 + t_a}}\right)}} \\ \dfrac{dW_a}{dt} = \dfrac{\left(1 - e^{-KLAI}\right) \cdot R_n}{\rho_a \cdot V \cdot \lambda \left(1 + \beta\right)} + \dfrac{q_s \cdot \left(W_S - W_a\right)}{V} \\ \dfrac{m_w C_f}{q_s C_a}\dfrac{dt_s}{dt} + t_s = \dfrac{q_x t_x + q_h t_a}{q_s} - \dfrac{q_w C_f}{q_s C_a}\left(t_{w2} - t_{w1}\right) \end{cases} \tag{6}$$

From the analysis of formula (6), the following conclusions can be drawn:

The factors affecting the temperature environment are mainly the volume flow of the supply air- q_s , the supply air temperature- t_s , the power of the artificial light source- p , the running time of the artificial light source- t_W , and the internal relative humidity- RH_{in} ; The factors affecting the humidity environment are mainly the volume flow of the supply air, the supply air content. Humidity-q_s, Supply air moisture content-W_s ,power of artificial light source- p , running time of artificial light source-t_w , internal temperature-t_a ; environmental factors that affect the temperature and air supply volume are mainly internal temperature-t_a , cold water flow in the fan coil-q_w, and cold water temperature difference.

4.2. Dynamic Model Verification of Ambient Temperature and Humidity Control

After the establishment of nonlinear temperature and humidity models, dynamic mathematical models are applied to system simulation and model-based controller design[15-16]. In order to ensure the accuracy of the dynamic model of environmental temperature and humidity control, in the plant factory, the artificial light source keeps running stably and the air treatment equipment works normally. The system state values at the steady-state operating point, that is, the calculated temperature and humidity values, and the temperature and humidity data of the system are collected and compared and analyzed to verify the accuracy of the dynamic model.

Therefore, in the system dynamic model (6), let $\vec{x}$ be the system state vector, $\vec{u}$ be the input vector, $\vec{y}$ be the output vector:

$$x = [x_1, x_2]^T = [t_a, W_a]^T \tag{7}$$

$$u = [u_1, u_2, u_3]^T = [q_w, q_s, W_s]^T \tag{8}$$

$$y = [y_1, y_2, y_3]^T = [t_s, t_a, W_a]^T \tag{9}$$

From $\vec{y} = \vec{u} \cdot \vec{x}$, get:

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \cdot \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix} \tag{10}$$

The accuracy of the dynamic model is verified through the on-site test. Combined with equation (6) and equation (10), the sovler function in MATLAB is used to calculate the system output value of the steady-state operating point in the actual field, and the output value is calculated. Compare with the measured values of steady-state operating points A, B, C, D, and E, as shown in Table 1 to Table 5, to determine the accuracy of the model.

During the experiment, the initial settings of the environment are as follows:

(1) The artificial light source is in a stable working state, that is, the working time is 12h/d (the light source is turned on from 20:00 to 8:00 the next day; the light source is turned off from 8:00 to 20:00 every day) The power of a single light source 400W, the number of light sources 8;

(2) In the plant factory, from sowing to growing to three-leaf and one-heart state, three time points are taken within the growth period, namely one-leaf and one-heart period, two-leaf and one-heart period, and three-leaf and one-heart period;

(3) The ambient temperature is set to 26℃ (light source on stage) and 16℃ (light source off stage);

(4) The ambient humidity is set to 70% (light source on stage) and 50% (light source off stage);

(5) The CO_2 concentration value is constant $440 \mu mol/mol$.

According to Table 1 to Table 5, the five steady-state operating point data of A, B, C, D, and E are divided into two stages (9:00 to 9:20 on the 21st, 9:00 to 9:20 on the 23rd , 9:00 to 9:20 on the 25th, the light source is on Analysis and Verification.

Table 1: Parameter values of temperature and humidity environment system of plant factory artificial light source (A)

	Parameter name	Parameter symbol	Environment status and parameter values					
Environment initial setup	Time point		August 21st 9:00	August 23st 9:00	August 25st 9:00	August 21st 21:00	August 23st 21:00	August 25st 21:00
	Growth state		One leaf stage	Two-lea f stage	Trefoil	One leaf stage	Two-leaf stage	Trefoil
	Thermometer constant	γ	$\gamma = 0.0646\text{kPa}/^{o}\text{C}$					
	Air supply capacity coefficient	k_s	$k_s = 1.21\left(\text{kJ}/\left(\text{m}^3 \cdot {}^{o}\text{C}\right)\right)$					
	Air density	ρ_a	$\rho_a = 1.199\left(\text{kg/m}^3\right)$					
	Constant air pressure specific heat	c_{ap}	$c_{ap} = 1.009\left(\text{kJ}/\left(\text{kg} \cdot {}^{o}\text{C}\right)\right)$					
	Cold water specific heat	C_w	4.18 $\text{kJ}/(\text{kg} \cdot {}^{\circ}\text{C})$					
	Cold water density	ρ_w	1000 kg/m^3					
	Fresh air ratio	$\frac{q_x}{q_s}$	30%					
	Specific heat of air	C_a	1.0 $\text{kJ}/(\text{kg} \cdot {}^{\circ}\text{C})$					
	Fan coil unit specific heat	C_f	0.39 $\text{kJ}/(\text{kg} \cdot {}^{\circ}\text{C})$					
Stable operating point measurement	The temperature difference between the inlet and outlet water of the fan coil	Δt	-3℃					
	amount of cold water	q_w	0.51 m^3/h					
	Work area volume	V	20.16 m^3					
	Leaf area index	LAI	4.35e-6	3.23e-5	7.07e-5	4.35e-6	3.23e-5	7.07e-5
	Leaf temperature	$\sum t_p$	26.2	27.1	27.9	19.4	18.2	15.2
	Fan coil inlet air temperature	t_{s1}	22	20	20	13	13	13
	Fresh air temperature	t_x	14	13	14	10	10	11
	Regional air humidity	W_a	11.89	11.35	12.09	12.42	11.71	11.65
	Air volume	q_s	5.22	5.18	5.22	5.62	5.58	4.94
	Supply air temperature	t_s	26	26	26	16	16	16

Calculate the value	Supply air moisture content	W_s	11.53	11.38	11.53	12.91	12.75	10.62
	Internal temperature	t_a	23.77	23.79	23.79	15.86	16.2	12.89
	Internal humidity	RH_{in}	61.87	59.82	62.95	57.72	55.12	65.83
Validate the value	Internal temperature	t_a	25.4	26.0	27.2	20.1	18.5	14.6
	Internal humidity	RH_{in}	63.6	62.1	64.7	60.2	58.4	69.2
Temperature	Absolute error	$\|t_a\|$	1.63	2.21	3.41	4.24	2.3	1.71
	Relative error	%	6.86	9.29	14.33	26.73	14.20	13.27
Humidity	Absolute error	$\|RH_{in}\|$	1.73	2.28	1.75	2.48	3.28	3.37
	Relative error	%	2.80	3.81	2.78	4.30	5.95	5.12

Table 2: Parameter values of temperature and humidity environment system of plant factory artificial light source (B)

	Parameter name	Parameter symbol	Environment status and parameter values					
Environment initial setup	Time point		August 21st 9:05	August 23st 9:05	August 25st 9:05	August 21st 21:05	August 23st 21:05	August 25st 21:05
	Growth state		One leaf stage	Two-leaf stage	Trefoil	One leaf stage	Two-leaf stage	Trefoil
Calculate the value	Internal temperature	t_a	23.69	23.56	23.77	15.86	16.14	12.73
	Internal humidity	RH_{in}	62.13	59.72	62.87	57.8	55	64.55
Validate the value	Iinternal temperature	t_a	25.5	25.9	27.1	20.1	18.5	14.5
	Internal humidity	RH_{in}	63.6	62.2	64.7	60.2	58.6	69.2
temperature	Absolute error	$\|t_a\|$	1.81	2.34	3.33	4.24	2.36	1.77
	Relative error	%	7.64	9.93	14.01	26.73	14.62	13.90
humidity	Absolute error	$\|RH_{in}\|$	1.47	2.48	1.83	2.4	3.6	4.65
	Relative error	%	2.37	4.15	2.91	4.15	6.55	7.20

Table 3: Parameter values of temperature and humidity environment system of plant factory artificial light source (C)

	Parameter name	Parameter symbol	Environment status and parameter values					
Environment initial setup	Time point		August 21st 9:10	August 23st 9:10	August 25st 9:10	August 21st 21:10	August 23st 21:10	August 25st 21:10
	Growth state		One leaf stage	Two-leaf stage	Trefoil	One leaf stage	Two-leaf stage	Trefoil
Calculate the value	internal temperature	t_a	23.64	23.79	23.72	15.91	16.2	12.81
	Internal humidity	RH_{in}	62.24	59.82	63.01	57.12	54.98	62.89
Validate the value	Internal temperature	t_a	25.7	26.2	27.3	20.2	18.7	14.8
	Internal humidity	RH_{in}	63.8	62.3	64.7	60.3	58.6	69.3
Temperature	Absolute error	$\lvert t_a \rvert$	2.06	2.41	3.58	4.29	2.5	1.99
	Relative error	%	8.71	10.13	15.09	26.96	15.43	15.53
Humidity	Absolute error	$\lvert RH_{in} \rvert$	1.56	2.48	1.69	3.18	3.62	6.41
	Relative error	%	2.51	4.15	2.68	5.57	6.58	10.19

Table 4: Parameter values of temperature and humidity environment system of plant factory artificial light source (D)

	Parameter name	Parameter symbol	Environment status and parameter values					
Environment initial setup	Time point		August 21st 9:15	August 23st 9:15	August 25st 9:15	August 25st 21:15	August 23st 21:15	August 25st 21:15
	Growth state		One leaf stage	Two-leaf stage	Trefoil	One leaf stage	Two-leaf stage	Trefoil
Calculate the value	Internal temperature	t_a	23.64	23.43	23.97	15.86	16.14	12.79
	Internal humidity	RH_{in}	61.88	61.48	62.15	57.14	54.72	62.81
Validate the value	Internal temperature	t_a	25.7	26.2	27.3	20.2	18.7	14.8
	Internal humidity	RH_{in}	63.8	62.3	64.7	60.3	58.6	69.3
temperature	Absolute error	$\lvert t_a \rvert$	2.06	2.77	3.33	4.34	2.56	2.01
	Relative error	%	8.71	11.82	13.89	27.36	15.86	15.72
humidity	Absolute error	$\lvert RH_{in} \rvert$	1.92	0.82	2.55	3.16	3.88	6.49
	Relative error	%	3.10	1.33	4.10	5.53	7.09	10.33

Table 5: Parameter values of temperature and humidity environment system of plant factory artificial light source (E)

	Parameter name	Parameter symbol	Environment status and parameter values					
Environment initial setup	Time point		August 21st 9:20	August 23st 9:20	August 25st 9:20	August 21st 21:20	August 23st 21:20	August 25st 21:20
	Growth state		One leaf stage	Two-leaf stage	Trefoil	One leaf stage	Two-leaf stage	Trefoil
Calculate the value	Internal temperature	t_a	23.56	23.69	23.77	15.86	16.27	12.6
	Internal humidity	RH_{in}	61.35	60.52	62.75	57.43	54.86	63.9
Validate the value	Internal temperature	t_a	25.7	26.3	27.3	20.3	18.7	14.9
	Internal humidity	RH_{in}	63.9	62.3	64.7	60.4	58.6	69.3
Temperature	Absolute error	$\lvert t_a \rvert$	2.14	2.61	3.53	4.44	2.43	2.3
	Relative error	%	9.08	11.02	14.85	27.99	14.94	18.25
Humidity	Absolute error	$\lvert RH_{in} \rvert$	2.55	1.78	1.95	2.97	3.74	5.4
	Relative error	%	4.16	2.94	3.11	5.17	6.82	8.45

5. Conclusion

1) To stabilize the ambient temperature of the working point, the average absolute error is 1.9 ℃, 3.4 ℃, and 4.1 ℃ in the light source-on stage, and the average relative pair error is 8.2%, 1.6%, and 18.1%; in the light source-off stage, the average absolute error is 4.7°C, 3.7°C, 2.8°C, the average relative error is 28.8%, 18, .8%, 19%. To stabilize the ambient humidity at the operating point, the average absolute errors are 1.8%, 2.0%, and 2.0% in the light source-on stage, and the average relative pair errors are 3.0%, 4.4%, and 4.6%; in the light-source-off stage, the average absolute errors are 2.8%, 3.6% , 5.3%, and the average relative error is 5.5%, 7.5%, and 9.2%. The overall relative error and absolute error are both small, indicating that the model is relatively accurate and can be used as a theoretical basis for subsequent research on the control environment.

2) The relative error of temperature, the light source on stage is greater than the light source off stage, indicating that the heat dissipation of the artificial light source has a certain influence on the ambient temperature; the relative error of the humidity is basically the same in the on and off stages of the light source, indicating that the heat dissipation of the artificial light source has a certain impact on the ambient temperature humidity has little effect.

3) The relative error of temperature and humidity is smaller than that in the one-leaf and one-heart stage of corn seedlings, indicating that the pain-increasing effect of crops has a greater impact on the internal environment. In addition, there are also some errors in the measurement process, which also causes relatively large reason.

4) In the temperature and humidity system of the plant factory, there is a strong coupling effect of temperature and humidity, which is also one of the reasons for the large relative error.

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