The Application of the Fuzzy PID Temperature Control System in Plant Factory

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Abstract: ***Temperature in the plant factory is a multi-variable, time-varying, nonlinear and large time delay complex control system, plants need different temperature parameters in the different stages of the growth cycle, The temperature characteristic parameter or structure will change with the load change or disturbance factor, and to optimize the temperature system overshoot, rise time and adjust time, a simple PID control is difficult to meet the control requirements, so the system adopts fuzzy PID to improve the performance of the temperature control system, System simulation was carried out using MATLAB, the experimental effect is ideal, it will has a good application prospect.***

Keywords: Plant factory; Temperature; Fuzzy PID;

1. Introduction

Plant factory is a kind of facility can realize high precision environmental control, internal plant can realize continuous and efficient production, the system can be not affected by the external environment condition restriction. Temperature plays a particularly important role on the growth of the plants, temperature can affect plant photosynthesis and respiration, the suitable temperature can significantly promote the photosynthesis, can shorten the growth period of plants and improve Plant production, extreme high and low temperature has much more impact on plant growth.

There is a delay of temperature measurement in the Plant factory, and the action of air conditioning also has certain delay, temperature measurement value differences in different regions, temperature is also influenced by light intensity and air humidity, plants of different growth cycle need different optimum temperature, so the temperature control system of plant factory is a nonlinear, time-varying and large time delay control object.

Temperature environment of the plant factory is a time-varying, nonlinear control object, so it is difficult to establish mathematical model [4], the fuzzy control theory is an important part of intelligent control, it is mainly used in various kinds of nonlinearity, hysteresis of the complex control system, fuzzy PID control does not need accurate mathematical model of controlled object.

1. The influence of temperature on the plant

The air temperature in the plant factory has a important influence on crop photosynthesis and respiration, in order to make the normal process to the growth and physiological function, plants of different growth cycle need different optimum temperature. In different growth periods, lettuce plants inside the factory optimum temperature as shown in table 1.

Table 1: Lettuce in plant factories within the optimum temperature (℃)

The name of the crops	The Suitable temperature	Germination period	Seedling stage		Harvest time	
			Light phase	Dark period	Light phase	Dark period
lettuce	Air temperature	18-20	15-20	12-14	18-20	12-15

2. The mathematical model of controlled object

Temperature acquisition and control has obvious delays, according to the experience , the transfer function of the controlled object:

$$G(S) = \frac{Ke^{-\tau S}}{Ts+1} \quad (1)$$

The size of the plant factory is long (a) x width(b) x high (c) = 5 m x 8 m x 3 m. Air conditioning ventilation frequency (N) = Air volume of air conditioner /space volume in plant factory, unit: time/hours, room temperature allows range of plus or minus 1.0, air changes N = 14 times per hour [1]. According to empirical formula:

$$\tau = \frac{9}{N} = 9/14 = 0.64 \quad (2)$$

$$T = \frac{90}{N} = 90/14 = 6.4 \quad (3)$$

$$K = \frac{1}{1+\frac{52}{N}\left[\frac{1}{a}+\frac{1}{b}+\frac{1}{c}\right]} = 0.29 \quad (4)$$

By the formula (1) - (4) , Plant factory temperature controlled object transfer function is：

$$G(s)=\frac{Ke^{-\tau s}}{Ts+1}=\frac{0.29e^{-0.64s}}{6.4s+1} \quad (5)$$

3. The application of PID

PID controller has been widely used in industrial production process control, discrete mathematical expression of PID controller as shown in formula (6) [3]:

$$U(k)=K_C\left\{e(k)+\frac{To}{T_I}\sum_{i}^{k}e(i)+\frac{T_D}{T_O}\left[e(k)-e(k-1)\right]\right\} \quad (6)$$

The PID controller output increment is:

$$\Delta U(k)=U(k)-U(k-1)=K_C\left[e(k)-e(k-1)\right]+K_I e(k)+K_D\left[e(k)-2e(k-1)+e(k-2)\right] \quad (7)$$

Select Z –N Parameters of the formula [2], the best parameters of PID controller:

$$KK_C=1.35(\tau/T)^{-1} \quad (8)$$

$$\frac{T_I}{T}=2.5(\tau/T) \quad (9)$$

$$\frac{T_D}{T}=0.37(\tau/T) \quad (10)$$

When the Sampling period is100 ms, by the above formula:

K_C =46. 55; K_I = 2. 909; K_D=110. 3; (11)

Under the guidance of the theoretical value, using matlab for parameter adjustment, ultimately determine the parameters for adjustment K_C=30、K_I= 2.5、K_D=4, according to plant growth and the actual need, the temperature value is set to 24 ℃, PID temperature control effect is shown in figure 1:

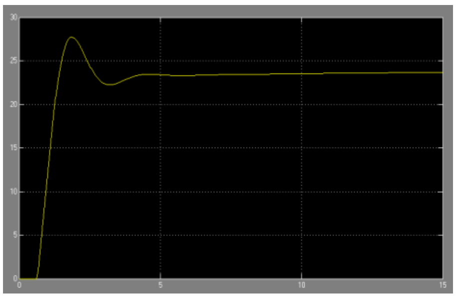

Figure 1: PID temperature control effect

2. The Design of the Fuzzy PID

In different stages of plant growth cycle need different temperature parameters, when the load changes, the temperature need change ,so the simple PID algorithm can not meets the requirement , the fuzzy PID can effectively solve the problem. According to the theory of fuzzy control and the functions of KP, ki and kd parameters, the conditions of fuzzy rules are expressed in a set, the k_p、k_i and k_d parameters can be expressed by the fuzzy rules.

Based on the relationship of temperature set value and measured value,the cotroller can calculate the error and error change rate, they can be used as the input of fuzzy PID controller, fuzzy PID control can modify the k_p、k_i and k_d parameters online.

The k_p role is to accelerate the response speed of syst em, the bigger k_p value, the faster response speed, but easy to produce larger overshoot amount. So when the temperature response curves in the initial stage of the rising process, increasing k_p can reduce rise time; W hen overshoot, reducing k_p value can down the oversh oot.

The k_i value is to eliminate the steady-state error, the bigger k_i value, the shorter time to eliminate error, but when the k_i value is too large, it is easy to produce the phenomenon of integral saturation.

The k_d role is to improve the dynamic performance of the system, when the temperature response will change in the process of deviation, k_d can forecast it in advance . But when k_d value is too large, the adjustment time will be longer.

In order to show the fuzzy rule adjustment effect, the k_p ,

k_i and k_d initial value is zero, and the fuzzy PID response result is shown in figure 2.

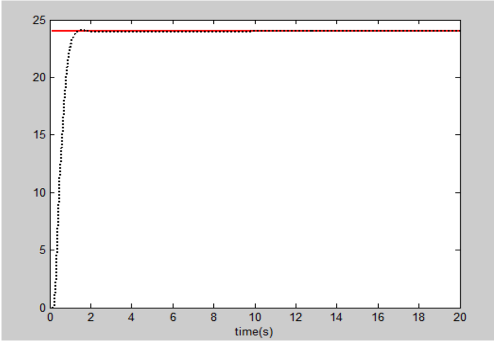

Figure 2: The fuzzy PID response result

Fuzzy PID control effect can be seen from the figure 2, the amount of overshoot is close to zero, but using PID control, the maximum overshoot temperature is 4 ℃, overshoot amount to 16.7%. Rise time is when the temperature value reach 90% temperature set point, the rise time need 1 second by fuzzy PID control, and the rise time need 2 second by the PID control .Above all, fuzzy PID control is better than PID control.

3. Conclusion

This paper analyzes the temperature that has a important effect on plant growth , temperature affect plant photosynthesis and respiration, When the temperature is set to the appropriate value, the control system can significantly improve the plant production and shorten the growth period. The temperature mathematical model of controlled object has been expressed, the PID and fuzzy PID temperature control system has been respectively analyzed, the simulation result indicates that the fuzzy PID control performance is better, and which can significantly improve the temperature control effect.

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