Wind Tunnel Wind Speed Control System Based on PLC Fuzzy Algorithm

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Abstract. With the deterioration of wind erosion, wind tunnel test has become an important method to study wind erosion. Wind speed control and data collection and processing are essential links in wind tunnel testing. The performance of wind speed control system directly affects the efficiency of wind tunnel test and the accuracy of test data. An incremental PLC fuzzy algorithm is used to realize the stable control of wind speed and improve the accuracy and reliability of the test, thus providing accurate and reliable experimental data for the study of wind speed control system in wind tunnel. And under the condition of large delay and instability, the PLC fuzzy algorithm can control the wind speed of wind tunnel more obviously. This paper takes the PLC fuzzy algorithm as the theoretical basis of the research, uses the fuzzy algorithm as the main research algorithm, integrates its important content to carry on the analysis research to the PLC fuzzy algorithm realization PID control to optimize the wind speed control system of the wind tunnel. Based on the classical wind tunnel wind speed control system, the PID control system is optimized and improved. PLC fuzzy algorithm can be regarded as a node sorting algorithm, so it can be used to construct wind tunnel wind speed control system. The experimental results show that this study has a better effect on the optimization design of wind speed control system by using PLC fuzzy algorithm to realize PID control.

Keywords: Fuzzy Algorithm, PLC, Wind Tunnel Wind Speed, Control System

1. Introduction

Using conventional PID control algorithms not only makes parameter setting difficult, but also does not give ideal results. The PID algorithm implemented by PLC fuzzy algorithm has the following characteristics in system design: it is not a mathematical model based on controlled process, is insensitive to the change of parameters, and has high stability. Therefore, it is better to use PLC fuzzy algorithm as the core PID control to design wind tunnel wind speed control system[1].Change of parameters and operating conditions of wind speed control system in wind tunnel, PID control is an automatic control equipment specially designed for industrial environment, and intelligent management of equipment is carried out[2].It has the characteristics of small volume, easy assembly
and maintenance, high reliability and strong anti-interference. It can not only perform logical control, but also perform data processing, communication and network functions. As a result, PID control is widely used in various fields of industrial control. Therefore, the application of PID control based on PLC fuzzy algorithm in wind speed control system has good effect[3].

A wind tunnel is a "man-made sky" on the earth, a pipe used to create artificial air currents (artificial winds). A pipe used by a force measuring device to drive an air flow at a controlled speed to compare a research model with a device used for aerodynamic testing[4]. As the most widely used tool in aerodynamics research and experiment, it can be directly used in scientific experiments and theoretical studies related to the basic laws of aerodynamics[5]. Wind tunnel wind speed control system is an important part of sea breeze kinematics and an important method and basic equipment for studying sea breeze kinematics. The experimental research using wind tunnel wind speed control system will not only be limited by natural conditions, greatly shorten the research period, save a lot of time, labor force and material resources, but also improve the research level. Better solve the practical problems of production and scientific research[6]. According to the statistical law of wind, the gust can always be regarded as the superposition of a large number of sine waves with different frequencies after analyzing by Fourier series method. In the frequency domain, the contribution of different frequencies to dispersion can be compared to analyze the basic frequency or period, so that the sinusoidal wind spectrum simulation can be regarded as the basis of gust simulation[7].

Wind tunnel wind speed control system developed with the development of electronic technology, before 1990s, mainly manual and semi-automatic, through manual operation of each operating valve or in the dynamic frequency converter to achieve wind speed control[8]. According to the current research situation of wind speed control system in domestic wind tunnel, the power system and control system are regarded as a whole, the automation degree of wind speed control is not high, and most of them use open loop to control wind speed. When wind tunnel wind speed is disturbed by external uncertain factors, it can not automatically mediate and control in real time. The actual wind speed is different from the required wind speed, which has a great impact on the experimental data[9]. The accuracy and reliability of the experimental data are greatly reduced. In order to improve the accuracy and reliability of experimental data. Because the classical control must be based on the accurate mathematical model, the nonlinear, multi-scale and complex information structure of the wind tunnel itself determine the establishment of the mathematical model is very complex[10]. The application of PID control under PLC fuzzy algorithm in wind tunnel wind speed control solves the difficulties of wind tunnel modeling and shows great advantages. In this paper, the control of wind tunnel wind speed control system is based on PID as controller, closed loop control mode and incremental PLC fuzzy algorithm. The error between wind speed and actual wind speed is minimized to improve the accuracy and reliability of the experiment.

2. PLC Fuzzy Algorithm

PLC Fuzzy Algorithm describes the fuzzy tracking problem, such as calculating the confidence plot to estimate the probability of the target, where the x is the target and the o is the tracker. Assuming that in the current image, the center position of the target is an automatic fuzzy function, because the PLC works according to the way of itinerant scanning, the programming method is different from the general microcontroller and has certain particularity. This is especially true in the implementation of complex control algorithms. On the basis of deep research and experiment, the key technology of PLC
fuzzy algorithm to realize PID control is summarized. The definitions are as follows:

\[ E = 2a \left( e^{-\frac{a+b}{b-a}} \right) \]  

(1)

\( I(z) \) represents the gray value at the point \( z \) and the automatically generated fuzzy region around the target center in the formula. Suppose that the two inputs of the two-dimensional fuzzy controller are the rate of change of the deviation \( x \) and the deviation \( m(x) \), while the output is the reference value of the controlled parameter in the controlled parameter:

\[ X = (\mathcal{W}_1, \mathcal{W}_2, \ldots, \mathcal{W}_k) \]  

(2)

The fuzzy data information has been added to the process of trust tracking and mapping: in order to make the work of the PID controller easier and to search the table, the negative range is first converted to the positive range, and then the device data is stored in memory PLC fuzzy algorithm indirectly using addressing instructions. The output is obtained by multiplying the data by the scale factor:

\[ x' = \{ c(z) = (I(z), z) | z \in \Omega (x') \} \]

(3)

\[ m(x) = P(x | o) \]  

(4)

In a series of collected images, different image frames close to each other change significantly in the area next to the moving target. By selecting two or more adjacent images to calculate the difference, the absolute value of the brightness of the changing region of the moving target can be determined. Use the ratio of target target position to the threshold and the formula for calculating the difference to determine the target position:

\[ \sum_{o \in x' \cap y'} p(x, c(z) | o) = \sum_{o \in x' \cap y'} p(x | c(z), o) p(c(z), o) \]  

(5)

\( p(x, c(z) | o) \) for PLC fuzzy algorithm, \( p(x | c(z), o) \) is PID Control Model PLC Fuzzy Algorithm.

3. Model Establishment Evaluation Results

The model is established according to the comprehensive evaluation method of PLC fuzzy algorithm to realize PID control. Evaluation Model is \( N_i = M^* R \), among \( N_i \) is results vector of prior evaluation for fuzzy comprehensive evaluation, \( M_i \) is Pre-assessment Index Weight Vector, \( R \) is Prior Assessment Evaluation Matrix, \(^*\) is operator notation. In fuzzy transformation, the selection of fuzzy operators also plays an important role in the scientific nature of the conclusion. There are four kinds of fuzzy operators commonly used:

(1) \( M(\wedge, \vee) \) operator, \( \wedge \) denote small, \( \vee \) means large. The operator rule is:

\[ B_k = \bigvee_{j=1}^{n} (a_{j,k} \wedge r_{j,k}) = \max \{ \min (a_{j,k} r_{j,k}) \} \quad k = 1, 2, \ldots, n \]  

(6)

(2) \( M(\bullet, \vee) \) operator, \( \bullet \) expression of multiplication. The operator rule is:
Features of the four operators in PLC fuzzy algorithms are shown in Table 1:

| Characteristics       | \( M(\land,\lor) \) | \( M(\lor,\lor) \) | \( M(\land,\lor) \) | \( M(\lor,\lor) \) |
|-----------------------|----------------------|----------------------|----------------------|----------------------|
| Role of weights       | Not obvious          | Obvious              | Not obvious          | Obvious              |
| Level of integration  | Weak                 | Weak                 | Strong               | Strong               |
| Access to information | Insufficiency        | Insufficiency        | More adequate        | Full                 |
| Type                  | Main factors         | Main factors         | Weighted average     | Weighted average     |

As shown in Table 1, through the above operation program, the value of the adjustment has been transmitted to a fixed address, and then what needs to be done is to make it clear by multiplying it with the scale factor, and the whole program is completed. Fuzzy rule base is a fuzzy information obtained by synthesizing triangle membership function and fuzzy algorithm according to the working experience of operators and the actual situation in the field. The evaluation of wind tunnel wind speed control system for PID control under PLC fuzzy algorithm is a comprehensive, scientific and objective evaluation. The influence model of PID control on wind tunnel wind speed control system is constructed by using the fourth operator.

4. Evaluation results

4.1. PIC Composition of Fuzzy Algorithm in PID Controller

In wind tunnel wind speed control system engineering practice, PLC fuzzy algorithm has strong adaptability in PID controller, Wind tunnel wind speed control will play a better effect. (PID control is a closed-loop continuous variable analog control, Control of pressure, temperature, flow rate, liquid level, etc. PID controller has high compatibility with PLC fuzzy algorithm, PID control can also be realized by PLC closed-loop control module. Programmable controller (PLC) is a closed-loop control module to achieve PID control, The programmable controller (PLC) can be directly connected to the ControlNet, Such as Rockwell PLC-5, etc. And controllers that can perform PID control, Such as Rockwell Logix product line, And it can be directly connected to ControlNet, Use the network to realize its remote control function. PID controller has become one of the most important industrial
control technologies with simple structure, good stability, reliable performance and simple configuration. On-site commissioning of wind tunnel wind speed control system, PLC fuzzy algorithm shows its good compression resistance and stability. PID control based on system error, And calculate the scale, Control variables of integral and differential control need PLC fuzzy algorithm. Inside the controller, PID controller first converts the analog feedback signal into a digital signal, Compare with the given wind speed signal to find the error and error change rate, PID control with PLC fuzzy algorithm, And output control signal. Transforming digital control signals into analog control signals, Finally, the wind speed is obtained. The test results show that, Wind tunnel wind speed control system configuration can be implemented by PLC fuzzy algorithm PIC controller, And the design meets the requirements. Hence, PLC fuzzy algorithm is a very economical, practical and easy to use method for wind tunnel wind speed control system.

4.2. Maximum Error Analysis

![Figure 1. Absolute error curve](image1)

![Figure 2. Relative error curve](image2)

The maximum absolute error and relative error analysis can be obtained by the PID control under the PLC fuzzy algorithm in figure 1 and figure 2 in the wind tunnel wind speed control system in terms of absolute error change and relative error change, Visible, At a target wind speed of 3 m/s-18m/s, Absolute error less than 0.12 m/s, And with the increase of the target wind speed, The
downward trend accords with the power law, similarity coefficient $R=0.9713$. The corresponding relative error is less than 4.5 when the target wind speed is $3 \text{ m/s}\sim18 \text{ m/s}$, And with the increase of the target wind speed, The downward trend accords with the power law, similarity coefficient $R^2=0.9921$. Wind erosion studies generally require winds above $5 \text{ m/s}$, The control error of the wind speed control system of the wind tunnel is enough to meet the requirements. In actual wind tunnel tests, The wind speed is the mean value of the wind speed within the sampling times, The results of the mean and mean error analysis of 15 samples at each target wind speed, As you can see from the data, The actual test wind speed is basically consistent with the target wind speed. Because wind tunnel wind speed test generally requires wind speed of more than $5 \text{ m/s}$, The control accuracy fully meets the requirements of wind tunnel test, The operation of the system can provide accurate and reliable wind speed test data for wind erosion research. This experiment tested the step response $\sim$ stability of the wind speed control system under the PLC fuzzy algorithm studied in this paper within $3 \text{ m/s} \sim 18$. Each index meets the requirements of wind tunnel wind speed test. The system steady-state error and airflow stability meet the requirements of accuracy and reliability of test data for wind tunnel wind speed test.

5. Conclusion

This study mainly realizes the control of PID control under PLC fuzzy algorithm in wind tunnel wind speed, that is, the control of PID controller through frequency input of frequency converter. An improved PLC fuzzy algorithm is used in wind tunnel wind speed control system to reduce the unstable start-up phenomenon caused by excessive instantaneous differential value. At the same time, in order to improve the accuracy of wind speed control, PID adjust the different proportion, integral and differential parameters according to the different wind speed sections, so that the precision of wind speed control is obviously improved. Through the research of PLC fuzzy algorithm control PID controller and software system of wind tunnel wind speed control system, the research of wind tunnel wind speed control system based on PLC fuzzy algorithm is carried out, and the automation degree of the system is improved. The accuracy of wind speed control not only meets the requirements of wind tunnel wind speed control system test, but also has good real-time performance, stable wind speed regulation, convenient operation and stable work. If necessary, the quantitative grade and the number of people can be extended on the basis of wind tunnel wind speed control system test to improve the control accuracy. Therefore, this study can achieve better and more accurate results for the control of wind speed control system by using PLC fuzzy algorithm to realize PID control.

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