Automatic Electromechanical Control System Based on PLC Technology

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Abstract. With the continuous progress of science and technology, China is transforming into the field of industrial automation, striving to contribute to the liberation of labor force and the realization of assembly line industrial automation. The operation of the traditional automatic electromechanical control system (AECS) still needs a lot of manual operation, which is difficult to realize the development of all automation of electromechanical control. The new AECS proposed at present is to realize the automation, intelligent and remote control of electromechanical control system, and truly take the control system as the center for electromechanical control production. Therefore, this paper puts forward the design and application of AECS based on PLC technology. Through research, this paper expounds the AECS based on PLC technology and its application. PLC technology can realize automation and integrated control in system control, compact structure, and can accommodate the conversion of many digital signals to realize its control function of the system, study the software design of AECS, mainly design the input interface and output interface. In order to understand the application and performance of PLC technology in automatic electromechanical system, this paper compares and analyzes the fuzzy PID control error of PLC technology and the performance of AECS based on PLC technology with traditional AECS. The experimental results show that in the comparative analysis of simulation experiments between the performance of AECS based on PLC technology and traditional AECS, the proportion coefficient of traditional AECS is 1.63, the integral time constant is -1.06, and the differential time constant is 0.29, while the proportion coefficient of AECS based on PLC technology is 0.56, the integral time constant is 0.37 and the differential time constant is 1.18. The deviation of AECS based on PLC technology is smaller than that of traditional automatic electromechanical control, and the static error is also smaller, but its response speed is faster and its performance is better.

Key words: PLC Technology; Control System; Automatic Control; Fuzzy PID Control

1. Introduction
With the continuous progress of society and the continuous development of science and technology, AECS has been widely used in the development of industrial production in China [1-2]. At present, the AECS used in China’s industrial production is mainly used to assist production personnel in automatic
production. Its degree of automation control is not high, and the unified operation of the control system is not realized [3-4]. Programmable controller (PLC) is an automatic control equipment specially used in industrial environment. It occupies a leading position in the field of industrial control and has made great development in control [5-6]. PLC has the characteristics of strong reliability and strong anti-interference ability. In terms of control, it has special simulator processing and professional PID data operation function, which is closely related to industrial automation control [7-8]. In order to realize a more controllable and convenient AECS, this paper adopts PLC technology for integrated control, and relies on the control system software design to ensure the automation of industrial production [9-10].

In the research on the design and application of AECS based on PLC technology, many scholars at home and abroad have studied it and achieved some research results. Some scholars pointed out that since the CPU of PLC is a digital signal processing mode, the application of PLC in analog control system should first realize the input and output function of PLC to analog quantity, and at the same time, it should also have high-speed data processing capacity and corresponding arithmetic operation function to realize the control purpose of PLC [11]. Other scholars pointed out that PLC is an industrial control equipment developed on the basis of integrated circuit and computer technology. It has the advantages of high reliability, good universality, strong anti-interference ability, simple programming, small volume, flexible configuration and convenient maintenance. It is widely used in various fields of industrial automation control [12]. These references about the AECS of PLC technology have a certain theoretical basis for the research of this paper.

This paper mainly studies the design and application of AECS based on PLC technology. Through research, this paper expounds the AECS based on PLC technology and its application. PLC technology can realize automation and integrated control in system control, and its structure is compact, which can be compatible with many digital signals for conversion to realize its control function to the system. This paper studies the software design of AECS, mainly designing the input interface and output interface. In order to understand the application and performance of PLC technology in automatic electromechanical system, this paper compares and analyzes the fuzzy PID control error of PLC technology and the performance of AECS based on PLC technology with traditional AECS.

2. The Design of AECS Based on PLC Technology

2.1. AECS Based on PLC Technology and Its Application

PLC technology is an industrial system control technology that relies on computer technology for digital control instead of relay logic control. It has strong reliability and anti-interference ability, and has special simulator processing and professional PID data operation functions in control. It plays a great role in industrial automation control, it is the preferred automation technology in the production process in the industrial field. PLC technology can realize automatic and integrated control in system control, compact structure, compatible with many digital signals for conversion, and realize its control function to the system. Its closed-loop control structure is shown in Figure 1.

![Figure 1. PLC closed loop control structure](image)

(1) Central processing unit CPU
Central processing unit CPU is the core part of PLC control system. It enables PLC technology to operate normally in the control system for control system action. CPU can accept and coordinate the main control system of PLC technology, collect the working environment data of PLC control system by scanning, and store the technical operation means contained in it in the memory of the control system for reference for subsequent control system operation. The CPU is responsible for driving the control system for operation, and the function is executed by running the control system operation stored in the read memory, so as to complete the automation of industrial production.

(2) Memory
Memory is mainly an existence similar to database, which can store the data in the whole operating system. After CPU completes the data collection of operation process steps, it will be stored in memory. The memory can read and call the data information stored in it, but can not change and delete the data information. The memory in PLC has the function of programming. While storing the read data, it can realize some data programming operations, such as real-time access to the operation data of the control system, reading and writing these data, in addition, it can be written according to the requirements of the control program, and the basic operation of the control system can be changed according to the specific operation guide and production requirements in the industrial production automation control.

(3) Input and output interfaces
The input and output interface is the part about data input and output in the PLC control system. This part is an important node for the intersection of data information in the automation of the control system and the control machine. The connection between input interface and output interface in the control system is controlled by CPU. The performance of input interface in the control system is mainly in the form of sensor, switch button, etc., and the performance of output interface in the control system is mainly in the form of display, indicator light, etc. In the input and output interfaces, the photoelectric coupling element is often used to design the control circuit, so as to reduce the influence of the signal in the environment on the control signal.

2.2. Software Design of AECS

(1) Input circuit design
The software design of AECS needs to pay attention to its input circuit design. The main forms of input circuit are sensors, switch buttons, etc., which requires the protection setting of voltage and current of the control system. The voltage form of PLC AECS selected in this paper is AC85 ~ 240V power supply, which has wider application range, stable performance and good adaptability. In order to prevent high voltage or short circuit in the control system, fuse mechanism and protection circuit shall be installed in the input circuit, and attention shall be paid to the design of voltage protection device. At the same time, the AECS shall prevent the interference of other circuit signals. In order to ensure that the AECS can accept the input of high-voltage current when necessary, double isolation technology is selected in the design of input circuit, isolation transformer and secondary coil shielding are installed, and the primary electrical neutral point is grounded to reduce the impact of high-frequency and low-frequency pulse waves.

(2) Output circuit design
The software design of AECS needs to pay attention to its output circuit design to ensure the normal and stable operation of the system. The output circuit is mainly in the form of display, indicator light and other external signals, and its design needs to maintain stability and safety. The output circuit design of automatic simulation planning electromechanical control system mainly includes program execution stage and output refresh stage. In the program execution stage, the CPU mainly scans sequentially according to the given program content, reads the corresponding operation commands
from the data instruction operation in the memory, generates commands, and controls the assembly to execute the program commands. The output refresh stage mainly includes refreshing the data scanning of the control system, refreshing the storage image register data and refreshing the output signal data.

2.3. Fuzzy PID Control Algorithm
In the computer control, the system deviation signal is obtained in the form of sampling, which is a discrete quantity. Therefore, the digital PID controller needs to be used. PID belongs to linear control, and its control deviation formula is:

\[ error(t) = rin(t) - yout(t) \]  

(1)

Where \( error(t) \) is the control deviation, \( rin(t) \) is the given value and \( yout(t) \) is the actual output value. PID control law is:

\[ u(t) = k_p error(t) + \frac{1}{T_i} \int_0^t error(t) dt + \frac{T_d}{T} \frac{derror(t)}{dt} \]  

(2)

Written as a transfer function:

\[ G(s) = \frac{U(s)}{E(s)} = k_p (1 + \frac{1}{T_i s} + T_D s) \]  

(3)

Where \( k_p \) is the proportional coefficient, \( T_i \) is the integral time constant and \( T_D \) is the differential time constant. The function of each link of the PID controller, the proportional link reduces the deviation, the integral link eliminates the static error, and the differential link improves the response speed.

3. Research and Analysis

3.1. Research Object
This paper mainly studies the design and application of AECS based on PLC technology. In order to understand the application and performance of PLC technology in automatic electromechanical system, this paper compares and analyzes the fuzzy PID control error of PLC technology and the performance of AECS based on PLC technology with traditional AECS.

3.2. Process Research Step
In order to understand the error analysis of fuzzy PID control of PLC technology, this paper converts the input variable into the corresponding quantitative value of fuzzy universe, samples the system deviation signal according to the quantitative value, studies the change rate \( e_c \) of control deviation according to the deviation \( e \) value, and understands the conditions of control error deviation value. In order to study the performance of AECS based on PLC technology, this paper compares it with traditional AECS through simulation experiments, and puts both systems into simulation application.

4. Experimental Research and Analysis of AECS Design Based on PLC Technology

4.1. Error Analysis of Fuzzy PID Control Based on PLC Technology
The design of AECS based on PLC technology needs to calculate the control quantization factor through fuzzy PID control. The quantization factor is used as the input interface of fuzzy PID controller to convert the input variable into the corresponding fuzzy universe quantization value. Samples are collected according to the quantization value to obtain the system deviation signal, and the control deviation change rate \( e_c \) is studied according to the deviation \( e \) value, the results are shown in Table 1.
Table 1. Corresponding relationship between deviation $e$ value and control deviation change rate $ec$

| $e$  | $\leq -200$ | $-200~-120$ | $-120~-40$ | $-40~40$ | $40~120$ | $120~200$ | $\geq 200$ |
|------|-------------|-------------|------------|----------|---------|----------|---------|
| $ec$ | $\leq -40$  | $-40~-24$   | $-24~-8$   | $-8~8$   | $8~24$  | $24~40$  | $\geq 40$ |
| $k_p$| -3.07       | -2.53       | -1.61      | 0        | 1.39    | 2.11     | 3.05    |
| $\Delta k_p$| 0 | 1.19 | 2.28 | 3.59 | 4.86 | 5.34 | 6.07 |

It can be seen from Table 1 that in the relationship between the deviation $e$ value and the control deviation change rate $ec$, when $e \leq -200$ and $ec \leq -40$, the increment $\Delta k_p$ of the proportional coefficient is 0, and the deviation quantization value of the fuzzy PID control in the PLC automatic control system is the smallest. When $e$ is between -40 ~ 40 and $ec$ is between -8 ~ 8, the proportional coefficient $k_p$ is 0, and the deviation quantization value of fuzzy PID control in PLC automatic control system is also small.

4.2. Performance Analysis of AECS Based on PLC Technology

In order to understand the performance of the AECS based on PLC technology, this paper compares and analyzes it with the traditional AECS through simulation experiments. By putting both systems into simulation, the proportional coefficient, integral time constant and differential time constant during their operation are collected and sorted out. The data results are shown in Table 2.

Table 2. Performance analysis of AECS based on PLC Technology

|                      | Proportional link | Integral link | Differential link |
|----------------------|-------------------|---------------|-------------------|
| Traditional AECS     | 1.63              | -1.06         | 0.29              |
| AECS based on PLC Technology | 0.56            | 0.37          | 1.18              |

Figure 2. Performance analysis of AECS based on PLC Technology

As can be seen from Figure 2, in the comparative analysis of simulation experiments between the performance of AECS based on PLC technology and traditional AECS, the proportion coefficient of
traditional A ECS is 1.63, the integral time constant is -1.06, and the differential time constant is 0.29, while the proportion coefficient of A ECS based on PLC technology is 0.56, the integral time constant is 0.37 and the differential time constant is 1.18. The deviation of A ECS based on PLC technology is smaller than that of traditional automatic electromechanical control, and the static error is also smaller, but its response speed is faster and its performance is better.

5. Conclusions
A ECS is the most common closed-loop control system in industrial production. It still has great limitations in industrial automation. If PLC technology is added to the A ECS, its automation level will be greatly improved, and the automation, intelligent and remote control of electromechanical control system can be realized, real electromechanical control production centered on control system. The design of A ECS based on PLC technology studied in this paper expounds the design and application of A ECS based on PLC technology, which provides a certain theoretical significance for the design and implementation of automatic mechanical control system.

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