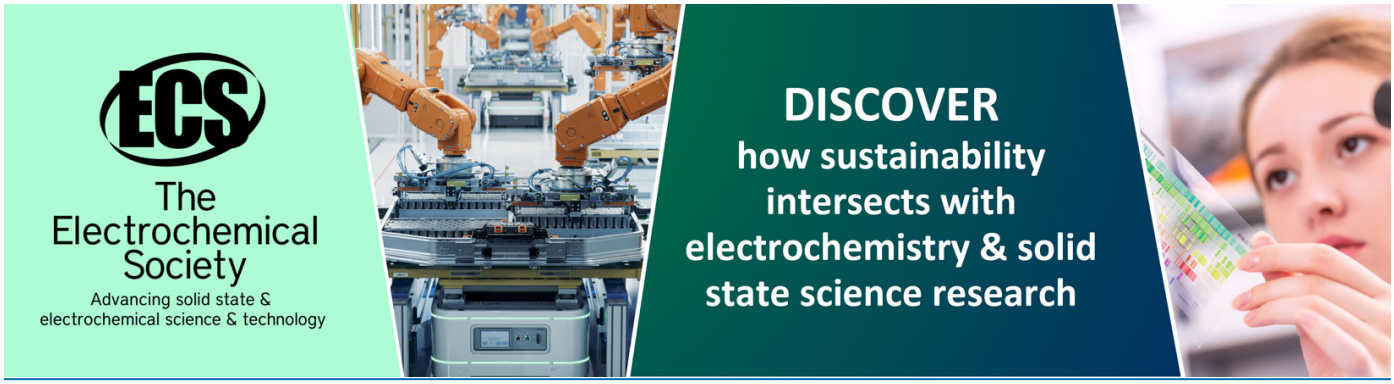
Design of Intelligent Greenhouse Control System based on MCGS and PLC



Design of Intelligent Greenhouse Control System based on MCGS and PLC

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Abstract. In modern agriculture, intelligent greenhouse systems have become a critical component for optimizing crop growth and maximizing yield. By integrating information technology with the isolation and climate control capabilities of greenhouses, these systems not only enable the automation and intelligence of agricultural production, but also play a crucial role in regulating seasons, protecting crops from extreme weather events, and ensuring optimal growing conditions. In this paper, a comprehensive control system for an intelligent greenhouse was designed, with Mitsubishi PLC and MCGS as the core components, based on the specific growth requirements of plants. The system consists of two main parts: hardware and software. The researchers constructed an advanced control system using a range of sensors and control devices, utilizing a typical PID control algorithm to maintain ideal growing conditions for plants. This research highlights the importance of intelligent greenhouse systems in modern agriculture and presents a promising solution for optimizing crop growth and yield through advanced automation and control.

Keywords. Mitsubishi PCL; Smart greenhouse; MCGS; Environmental control; PID control algorithm

1. Introduction

As a large agricultural country, China's modernization of agriculture relies on agricultural modernization as a support and foundation. By using information technology tools in agricultural production, it can help solve problems related to the shortage of human resources in rural areas and improve the efficiency of agricultural production. This leads to the transformation of labor-intensive agricultural production to technology-intensive [1]. Greenhouses are widely used in fruit and vegetable production, particularly during seasons when plants are not suitable for growth. They provide a suitable artificial environment, facilitating counter-seasonal output and growth of crops. However, with the modernization of agriculture, the artificial conditions and agricultural environmental information in greenhouses, such as light, CO2 concentration, soil moisture, temperature and air humidity, are putting forward higher requirements. The promotion of automated control and monitoring of greenhouse systems is an effective guarantee for achieving high crop yield and quality. In this paper, a smart greenhouse control system is designed using Mitsubishi PLC and

MCGS as the core of the underlying control. It provides ease of use and high stability, offering a good growing environment to promote the improvement of cultivation level.

1.1. Important Factors of Smart Greenhouse

Light intensity is critical to the photosynthesis of any crop, and different types of crops require varying levels of light intensity to promote normal growth [2]. Humidity is a key factor in the growth of crops, and maintaining it within a certain range is crucial to prevent pests and diseases and promote crop growth [3]. Temperature, including plant body temperature, soil temperature, and air temperature, is essential for the growth of crops, and controlling soil and air temperatures in smart greenhouses is necessary to ensure healthy crop growth [4].

1.2. System Function Introduction

The smart greenhouse control system designed in this study is based on MCGS and Mitsubishi PLC, providing four functions: automatic ventilation, automatic insulation, automatic water replenishment, and automatic light replenishment. The system operates in two modes: automatic and manual. In automatic mode, the PLC controls light conditions, humidity, and temperature settings in advance, facilitating various functions such as automatic light replenishment, automatic water replenishment, automatic heat preservation, and automatic ventilation. In manual mode, the switch needs to be turned on to complete the ventilation, heat preservation, light replenishment, and water replenishment functions. The system can detect and control factors affecting the greenhouse environment, including soil temperature, humidity, air temperature, air humidity, and light level, providing optimal growing conditions for greenhouse crops.

2. System Control Scheme Design

In this study, the system was designed to implement a manual combined with automatic control method, in which the daily operation is based on manual control, and the control buttons can be switched to manual control if necessary, which helps to enhance the stability of this equipment. In the system, manual control consists of electrical components such as relays, equipment operation limit switches, equipment control switches, and AC contactors, which have the advantage of reliability and simplicity. In the Mitsubishi PLC automatic control system, automatic control methods were used. Sensors can collect data on greenhouse environmental factors, which helps to analyze and monitor data. The lower and upper limits of the environmental factor data were then set, and when the system monitors a certain Han static factor value higher or lower than the set value, the Mitsubishi PLC is able to control this device to maintain the greenhouse environmental factor within a stable range; and the MCGS touch screen, as a human operator interface, can facilitate the realization of parameter monitoring and adjustment. At the same time, this system has the advantages of low operating cost and simple equipment, which can reduce the labor intensity of greenhouse management and thus improve the work efficiency [5].

2.1. System hardware

The core part of this system designed in this study is the automatic greenhouse control, consisting of components such as detection circuits, interface circuits, sensors, and field control systems. A key component is the sensor, which transmits crop-related environmental factors such as illumination, humidity, and temperature to the Mitsubishi PLC, which analyzes the environmental factor data and then uses the pre-set thresholds as the basic basis to generate intelligent decisions in combination with PID algorithms, and then transmits the generated control signals to relays to generate actuators, such as fill lights, solenoid valves and motors, etc., thus facilitating the implementation of intelligent greenhouse environmental automatic control, as shown in Figure 1. At the same time, when the parameters reach the preset parameters in the control system, the system can automatically link with the greenhouse internal and external actuators, which can automatically control the greenhouse environment, so that the greenhouse crop growth environment needs to be met, thus promoting the

realization of the automation and intelligence of the greenhouse environment, the specific implementation scheme of the control system is shown in Figure 2.

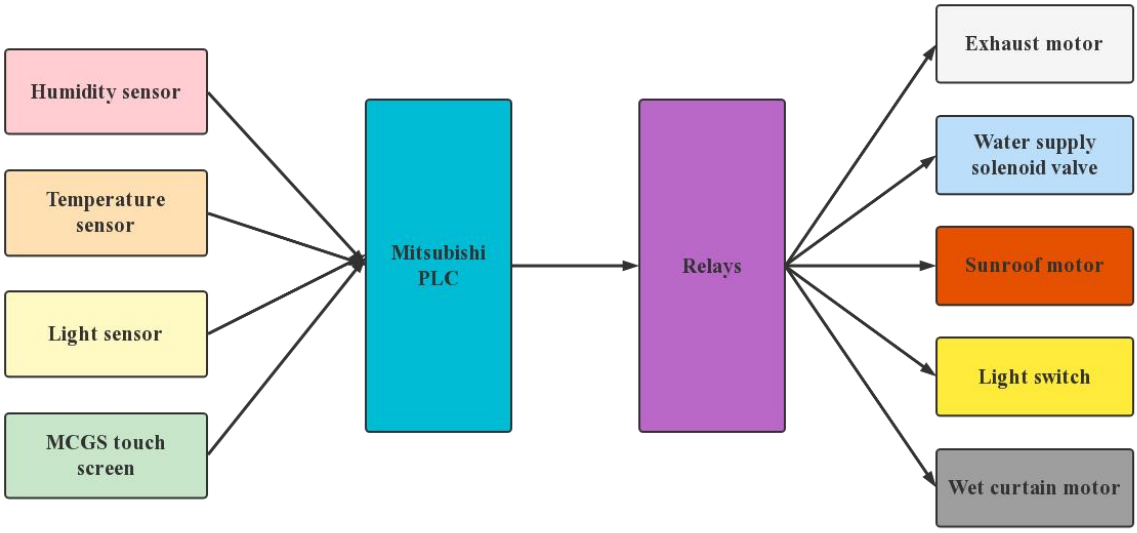

Figure 1. Control System Structure Diagram

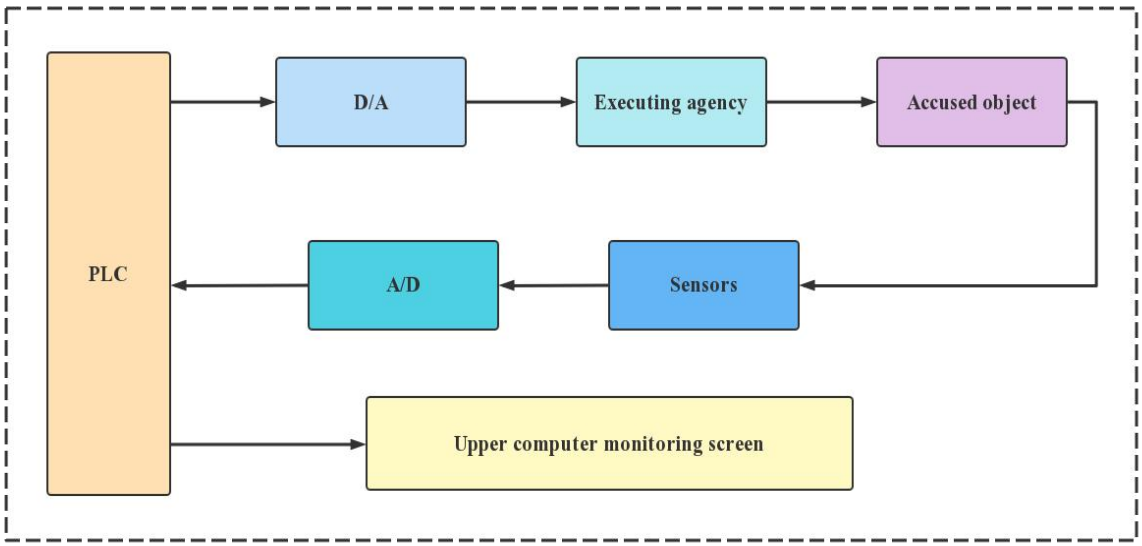

Figure 2. Control System Execution Scheme

2.2. Sensor selection

2.2.1 Light sensor. Generally speaking, the sensor light intensity can be measured by using silan photovoltaic detector. Its high sensitivity to weak light has many advantages such as the ability to transmit over long distances, ease of use, strong water resistance, good linearity and a wide measurement range [6].

2.2.2 Temperature and humidity sensor. This sensor is a composite design in which the temperature-sensitive element is a platinum resistor and the moisture-sensitive element is a polymer film moisture-sensitive capacitor. This sensor has a measurement range of 0-100%Rh and a temperature

measurement range of -40-120° C, and has a short response time, a wide range. It is easy to use and has a high measurement accuracy.

At the same time, in order to ensure the reliability and stability of the sensor output signal, in this study, 2 modules of Mitsubishi FXON-3A analog were used to read the 4-20mA current signal of air temperature and humidity and soil temperature and humidity, where 1# was able to read the analog signal of the soil humidity sensor; while 0# was able to read the analog signal of the air temperature and humidity sensor, as shown in Figure 3.

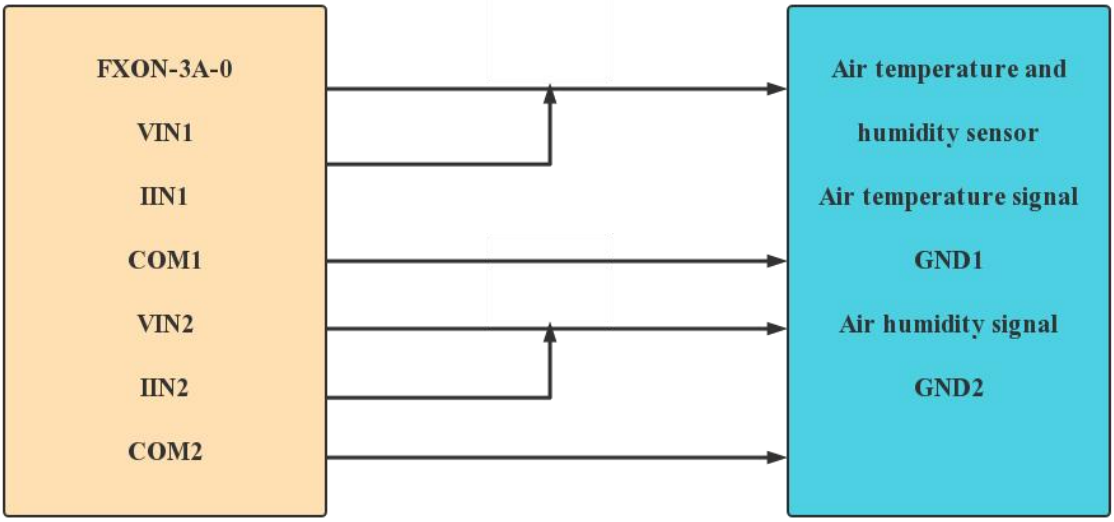

Figure 3. Air Temperature and Humidity Sensor and Modulus Module Wiring Diagram

3. System Software Design

3.1. Study of control algorithms

Usually, in continuous control systems, the PID control method is dominant and its control law can be expressed according to the following equation.

$$u\ （t）= K_p[e\ （t）+ \frac{1}{T_1}\int_0^t e(\mathrm{t})\mathrm{dt} + T_D \frac{de\ （t）}{dt} \tag{1}$$

After discretizing the above equation, the specific expression equation is as follows.

$$\begin{aligned} u(k) &= K_p\left\{e(k) + \frac{T}{T_1}\sum_{i=0}^{k} e(\mathrm{i}) + \frac{T_D}{T}[e(k) - \mathrm{e(k-1)}]\ \right\} \\ &= K_{pe}(k) + k_I \sum_{i=0}^{\mathrm{k}} \mathrm{e(i)} + K_D[e(k) - e(k-1)] \end{aligned} \tag{2}$$

In the above equation, the scale factor is represented by K_p; the output of the regulator at the kth sampling is represented by u(k); the deviation value at the (k-1)th sampling is represented by e(k-1); and the deviation value at the kth sampling is represented by e(k).

$$\mathrm{Kp}\frac{T}{T1} \text{ - integral factor} = \mathrm{K_1} \tag{3}$$

$$\mathrm{Kp}\frac{T_D}{T1} \text{ - differential factor} = \mathrm{K_D} \tag{4}$$

In agricultural production management, because in agricultural production, the accuracy of control is not high,intelligent greenhouse environmental control system as a system of automation only needs a zone. For example, regarding the humidity requirements of the greenhouse, the crops do not have high requirements and only need to maintain a suitable range within a certain growth cycle, then the normal growth of the crops can be guaranteed [7]. Therefore, it is not necessary to precisely control the greenhouse environmental factors, and according to the PID control algorithm, it is possible to study the differential part and to construct the differential equation that meets the conditions as follows.

$$T = \frac{dT_n}{d_t} + T_n = K(T_s + T_f) \tag{5}$$

In the above differential equation, the ambient temperature inside the greenhouse is represented by T_n; the number of changes generated by the conversion of the heat outside the greenhouse to the supply air temperature is represented by T_f; the time constant of the greenhouse is represented by T_s; and the fixed amplification factor of the greenhouse is represented by K [8].

3.2. Mitsubishi PLC Control Software Design

3.2.1 Design principles. In the design of intelligent greenhouse environmental control system, the core part is Mitsubishi PLC. It uses relays to be able to control the corresponding equipment, but the design should follow the following principles: (1) Greenhouse set up more than 8 skylights or by more, which control the skylight by the motor is responsible for. If the set temperature is high, the PLC can open the skylight to send the corresponding signal. Then it opens the skylight through the relay, and then stop the motor control according to the switch [9]; (2) The problem can be solved by using a self-locking circuit in order to prevent the misoperation of the equipment. (3) If the temperature and humidity continue to rise and reach a certain value, the fans can be turned on and 2 groups of fans are installed in the greenhouse and the temperature can be used as a basic basis for the control of the number turned on; (4) By using PLC in the system, the related problems can be solved; (5) Using light sensors to detect the sunlight illumination and if it is higher than a certain value, the shade net is turned on [10]. (6) After the humidity temperature drops to a certain level, the wet curtain water pump can be turned on; (7) This system has the function of switching between manual or automatic. According to a switch on the switch cabinet can be the signal input, so as to freely switch between automatic and manual control procedures; (8) As the temperature continues to rise, the wet curtain water pump needs to be turned on and the temperature is reduced using the wet curtain [11].

3.2.2 Software design. In the intelligent greenhouse environmental control system, Mitsubishi PLC can be used to control wet curtains, shades, fans, and skylights. It can use sensors as the basic basis to detect the relevant data, and then combine them with certain algorithms to send out control signals and use relays to control the start/stop of the equipment and the corresponding mechanism. In raising the temperature, the following process can be used, as in Figure 4.

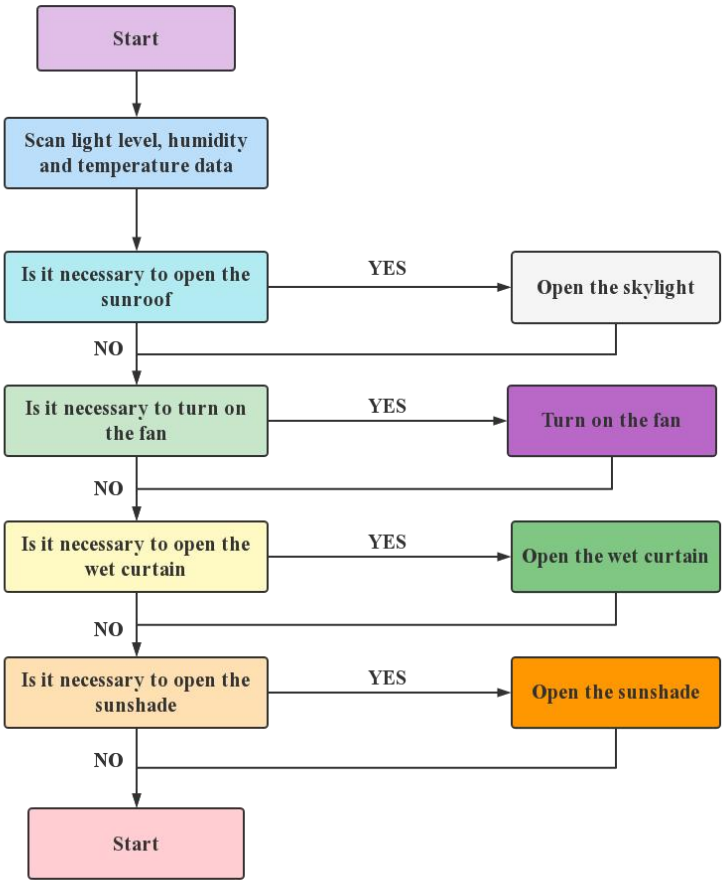

Figure 4. Mitsubishi PLC Control Algorithm Program Flow Chart When Temperature Rises

Algorithm description: First, the PID control algorithm as the basic basis, the illumination, temperature and humidity sensors to scan, and then based on differential equations, combined with humidity, illumination and temperature thresholds, to determine whether the skylight needs to be opened with the Mitsubishi PLC, if necessary, the skylight signal to open. Then this system can be based on the humidity and temperature in the greenhouse, the need to open the wet curtain to determine, if it is necessary to open the wet curtain, then send the solenoid valve signal. After that, a judgment is made on whether the fan needs to be turned on, and if the fan is to be turned on, the fan needs to be turned on. Finally, a judgment needs to be made on whether the shade needs to be turned on in combination with the light level and temperature. If the demand is there, this switch will be turned on.

4. MCGS Configuration Interface Design

MCGS configuration software is a software used for human-machine interface (HMI) design and PLC programming. It helps users create and configure control interfaces to monitor and control equipment. Specifically, in this software, you can create an interface to display relevant parameters of the greenhouse environment, such as soil humidity, temperature, environmental humidity, and temperature, and then use corresponding sensors to obtain these parameters in real-time and display them on the interface.

In addition, MCGS configuration software also supports arbitrary modification of environmental parameters, allowing users to more flexibly control environmental conditions. It also provides a function to switch working modes, allowing users to adjust the operating mode based on different working states of the equipment. Furthermore, MCGS configuration software can monitor the changing trend of environmental parameters, allowing users to better understand the trend of

environmental changes. These features make MCGS configuration software a convenient and easy-to-use tool that can help users better control and monitor the greenhouse environment [12-14].Greenhouse Environment Monitoring System Interface Design, See Figure 5.

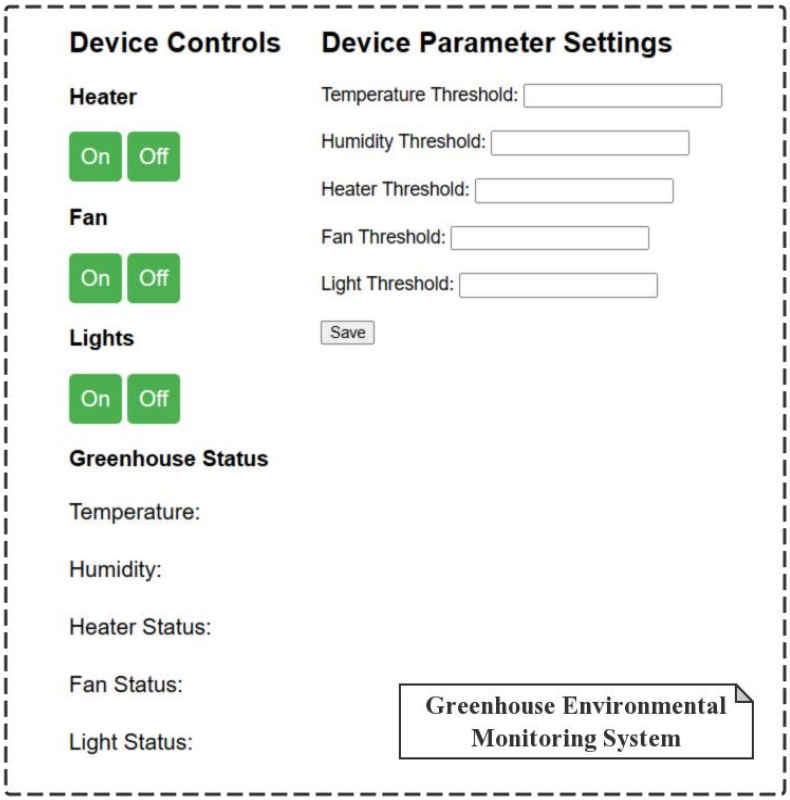

Figure 5. Greenhouse Environmental Monitoring System

5. Performance Testing and Analysis Results

In order to verify the reliability and effectiveness of this system, a small greenhouse with an overall volume of 20 m3 was selected for testing the performance of the system. 1 drip irrigation equipment, 1 sprinkler irrigation equipment, 4 ventilation fans, 1 fill light, 1 heat preservation lamp, 2 light level sensors, 4 soil temperature and humidity sensors, and 4 air temperature and humidity sensors were installed in the greenhouse. The purpose of this test is to judge the control effect of illumination, humidity and temperature, in which the upper limit of humidity is 80% and the lower limit is 30%, the lower limit of temperature is 16°C and the upper limit is 28°C, and the illumination is set to 3000 Lux. In the process of the test, the data of humidity and temperature control effect were analyzed, and the overall operation effect was evaluated. The results showed that the humidity exceeded the lower and upper limits were adjusted by 0.2h, and the normal humidity could be restored; the temperature exceeded the lower limit was adjusted by 0.4h, and the upper limit was adjusted by 0.3h, and the normal temperature was restored. It can be seen that this system can effectively control the humidity and temperature of the intelligent greenhouse, and the intermediate transition process takes a long time, but the system stability is good[15-17]. The performance test results are shown in Table 1, and the humidity control effect and temperature control effect can be seen in Figure 6 and Figure 7, respectively.

Table1. Performance Test Results Analysis

Parameter	Set Value	Test Value	Time Exceeded
Humidity	30%~80%	Normal	0.2h
Temperature	16°C~28°C	Normal	Lower Limit 0.4h,

			Upper Limit0.3h

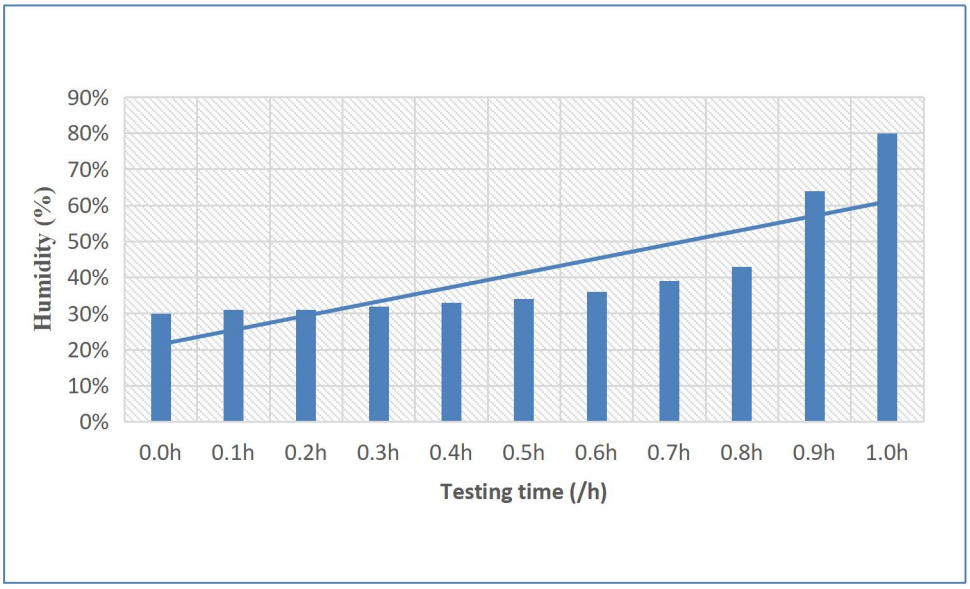

Figure 6. Humidity Control Effect Graph

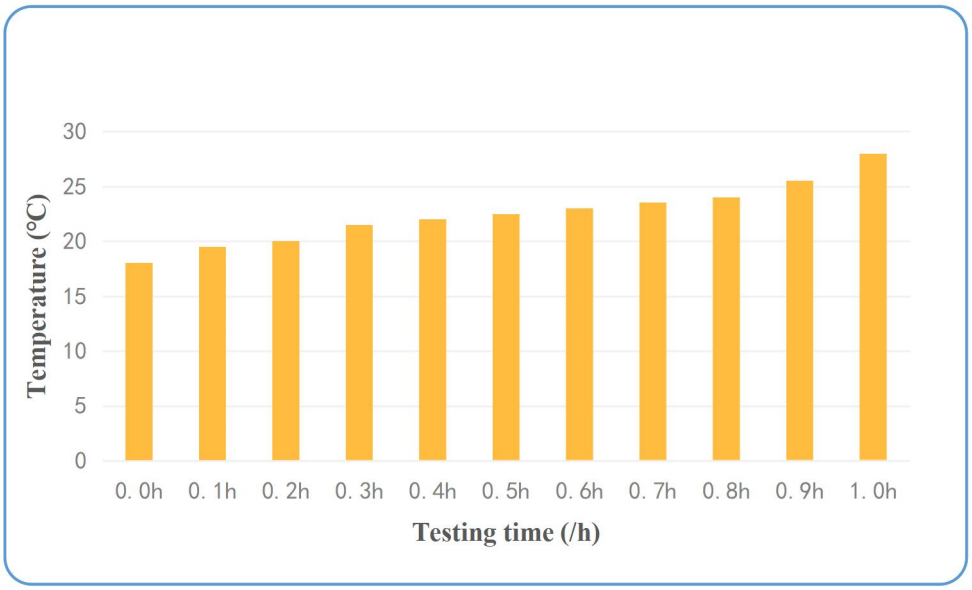

Figure 7. Temperature Control Effect Graph

6. Conclusion

In summary, the intelligent greenhouse environmental control system based on Mitsubishi PLC can set the environmental parameters according to the actual growth needs of crops, which helps to control the greenhouse environmental illumination, humidity and temperature, and provides a good growing environment for crops. At the same time, MCGS configuration environment can adjust the relevant parameters, simplify the operation of the control system, the reliability and stability of this system is high, especially can control the greenhouse environment, and better performance, has the value of promotion and application.

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8. References

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