Control System of Aeroponics in Sunlight Greenhouse

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Abstract. At present, there are problems of low accuracy in environmental control, instability of the system and small planting area in the process of aeroponic production. As a result, the advanced and new technologies of aeroponic production can’t realize high yield, quality and efficiency to the maximum. In order to solve the problems, PLC is used to monitor the PH/EC values of nutrient solution in liquid storage pool, the temperature of nutrient solution, the level of nutrient solution, the hydraulic pressure of main pipeline, the temperature and humidity of cultivation bed. Besides, PLC controls the time of water pump motor and the switch of solenoid valve in regional main pipelines. In addition, PLC can realize the real-time monitoring and control of plant growth environment accurately, especially the root growth environment. The production system will make further efforts to improve the automation and intelligence of the production process and promote to create conditions for the realization of high-quality, high-efficiency and high-yield in the process of the technology of aeroponic production.

Introduction

Aeroponic culture is a new technology of soilless culture which integrates plant nutriiology, plant physiology, ecological environment, agricultural automation, horticultural crop cultivation and other disciplines. This technology is the process of growing plants in an air environment, which better meets the plants’ requirements of water and fertilizer and creates new root environment in place of the soil and substrate environment[1]. And the problem of the moderation and balance of water and oxygen supply of plant roots in traditional soil cultivation and hydroponics will be efficiently solved, which makes it easier for plant roots to be in the most suitable environment than any other cultivation patterns, so as to bring the potential of crop growth into full play and improve the plant quality and yield[2, 3]. The control of aeroponic culture environment is the core of aeroponic production and is also the main factor restricting the production of aeroponic culture. This paper aims to design an intelligent aeroponic production system in sunlight greenhouse to achieve more precise control of aeroponic production and create conditions for high quality and efficient production under aeroponic culture environment.

Composition and Working Process of Aeroponic Production System

The whole production system of aeroponic culture consists of a liquid storage pool, a liquid supply and return system, a control system, a cultivation bed and so on. The Figure 1 shows how it works.

The working process of aeroponic production system includes nutrient solution supply process and nutrient solution reflux process.

- Nutrient solution supply process. This process supplies liquid to regions in turn. And liquid supply conditions in each region are the same. In each liquid supply section, the nutrient solution is drawn into the main pipeline by a constant and stabilized pressure pump through a suction pipe, filtered and sent to the regional main pipelines. Then, the nutrient solution passes through the branch pipeline and the sub-pipeline of each region in turn and enters the atomization pipeline. Then the nutrient solution is atomized to the plant roots by an atomization nozzle hanging upside down inside the cultivation bed.
• Nutrient solution reflux process. The unabsorbed nutrient solution drips down along the roots to the bottom of the cultivation bed, then flows through the branch reflux pipeline and the main reflux pipeline, and finally flows into the storage pool through the filter screen installed in the filter pool.

Figure 1. Working principle of Aeroponic Culture Production System.

Control System Framework

In order to better monitor and control the production environment of aeroponic culture in real time, make the nutrient solution more conducive to plant growth in all aspects of production and ensure that the plants are in the best growing environment, the control system includes: PH/EC value monitoring of nutrient solution in liquid storage pool; temperature monitoring of nutrient solution in liquid storage pool; water level monitoring in liquid storage pool; time control of water pump motor; hydraulic pressure monitoring of main pipeline; accurate switching control of solenoid valve in regional main pipelines; temperature and humidity monitoring in cultivation bed. The control system is distributed in the supply process.

Figure 2. Control System Framework.

The control system framework is shown in Figure 2. This system can adopt two modes: manual operation mode and automatic operation mode, and at the same time, remote monitoring and control can be realized through human-machine interaction interface from upper computer. The system...
transmits instructions by the software controlled by upper computer or monitor the environment conditions by various sensors. The PLC controller controls the working state of the constant and stabilized pressure pump, heater and regional solenoid valve according to the environmental state. At the same time, for the convenience of users, the system can be accessed by mobile phones. Users can access to the system through mobile APP to implement the same monitoring and control functions as the upper computer.

Control System Program Process

![Control System Program Process Diagram](image-url)

Figure 3. PLC Control System Flow Chart.

The flow chart of the whole control system is shown in Figure 3. The parameters in the control system are set manually or automatically by the control strategy. When working, the PLC controller controls the work of the components by whether the sensors monitoring values are within the threshold values. When the system is running, the temperature and PH/EC values of the liquid storage pool are monitored firstly, and the system begins to supply the liquid when the values are within the threshold values. When the PH value or EC value in the liquid storage pool exceeds the set range, the fuzzy control strategy is adopted to add alkali, acid, salt or fertilizer to the liquid storage pool, so that the PH value and EC value in the liquid storage pool can reach the preset range. The system monitors the working state of supplying liquid in real time and polls to supply liquid to each region. And at the same time, a temperature and humidity sensor is installed in the terminal cultivation bed of each liquid supplying region. When the humidity is below the set threshold value, the system stops polling for liquid supply and gives priority to liquid supply in regions where humidity is not enough. And when the humidity of the regions reaches the set range, the polling for liquid supply restarts. When the temperature is below or above the threshold value, the system monitors the temperature of nutrient solution and stops heating. The relationship between the temperature of the liquid storage pool and the temperature of terminal cultivation bed of each liquid
supply region as well as the threshold values of them are given according to different crop growth models.

**Design of Major Control Components**

**Function Modules of Control Software**

The system software includes four modules: system settings, operation modes, parameters settings and control mode settings. The software function modules are shown in Figure 4.

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- **System settings** mainly include system login, account and permission settings and communication interface settings.

- **Operation modes** include automatic operation mode, manual operation mode and real-time display of sensor data. And the real-time display of sensor mode includes real-time display of sensor data and sensor graphics; sensor historical data and statistical data curve.

- **Parameters settings** mainly include water level threshold value and settings of liquid storage pool, temperature and humidity threshold values and settings of liquid storage pool, pressure threshold value and settings of pipelines and other settings. And the other settings mainly include time settings of polling for spray in different regions, PH/EC control strategy settings and temperature control strategy settings and so on.

- **Control mode settings** mainly include seasonal control strategy settings, daily period control settings and crop growth model settings. Seasonal control mode includes the control strategy settings of heating and non-heating seasons. According to the growth characteristics of different crops, the demand for light and temperature in a day varies. Consequently, daily period control settings divide a control period day into four periods: forenoon, afternoon, evening and night.

- **Crop growth models** are set up according to different temperature and humidity requirements of different crops in different growth cycles, such as germination, seedling, flowering and fruit stages.

**PH/EC Values Monitoring of Nutrient Solution in Liquid Storage Pool**

A PH/EC values sensor for nutrient solution is installed on the wall of the liquid storage pool 1m away from the suction pipe between the lowest water level sensor and the end of the suction pipe of constant and stabilized pressure pump. The data of PH and EC values are transmitted to the control terminal and can be monitored in real time. In the application of a nutrient solution, the regression line between the PH/EC values of nutrient solution and the volume of mother liquor is obtained by experiment. By presetting the basic parameters of the nutrient solution proportioning, when the measured PH/EC values reach the preset ones, the amount of mother liquor and water will be calculated. When the PH and EC values are lower than the set values, the control system alarms and automatically display the amount of mother liquor and water that are needed to supplement nutrient solution on the upper computer software interface.
Monitoring of Nutrient Solution Temperature in Liquid Storage Pool

A cast aluminum plate heater is placed at the bottom of liquid storage pool, and a liquid temperature sensor is installed at 40 mm above the heater. The temperature of nutrient solution in the liquid storage pool is monitored in real time, so that the temperature is kept at the setting temperature that is beneficial for plant growth. When the temperature monitored by liquid temperature sensor is below the set value, the relay controlled power supply of plate heater starts to work, and the heater is heating slowly. When the temperature reaches the set point, the heating stops and the process proceeds in cycles. In order to make the monitoring more accurate, multiple liquid temperature sensors are used to determine the accuracy of monitoring results by comparing the monitoring values. If the monitoring temperature and temperature difference are not within the set range, the control system immediately stops supplying liquid to prevent the damage to the plants because of excessively high or low temperature caused by the fault of temperature sensors.

Monitoring of Water Level in Liquid Storage Pool

Two liquid level sensors are installed on the wall of the liquid storage pool, and they are hung upside down separately at the lowest and the second lowest liquid levels on the wall of the liquid storage pool. The warning water level can be adjusted by raising or lowering the liquid level sensors. When the nutrient solution level in the liquid storage pool drops and the second lowest liquid level is exposed, the control system alarms. When the liquid level sensor at the lowest liquid level is exposed, the water pump motor stops working and an alarm is given to prompt the supplement of nutrient solution.

Time Control of Water Pump Motor

Because the aeroponic environment doesn’t need continuous liquid supply, the liquid supply pump works at regular intervals, and the working time and duration are set by the upper computer software or mobile phone terminal.

Monitoring of Hydraulic Pressure in Main Pipeline

The pressure sensor is set near the water pump in the main pipelines. The detection values are monitored by pressure sensors in real time and displayed on the LCD. When the hydraulic pressure of the main pipeline is abnormal, the power supply of the constant and stabilized pressure pump is cut off by the control system, and the warning alarm is given.

Switch Control of Solenoid Valve in Regional Main Pipeline

The control of solenoid valve cycle conduction is adopted to supply nutrient solution in turn to regional main pipelines. The on-off time information of the solenoid valves is displayed on the LCD. Only one solenoid valve can work every time. When the hydraulic pressure of liquid supplying pipelines is abnormal due to the fault of solenoid valves, the power supply will be cut off through the monitoring values of the pressure sensors and the warning alarm starts in order to protect the equipment and pipelines. The conduction time, interval time and conduction sequence of solenoid valves in each region can be controlled by the software interface of the upper computer.

Monitoring of Temperature and Humidity in Cultivation Beds

The cultivation bed is a vertical planting carrier for plants, and its interior is the space for plant roots to absorb nutrient solution. A temperature and humidity sensor is installed in the cultivation bed which is the farthest from the main pipe in each liquid supplying region. The software interface of the upper computer displays the temperature and humidity in real time, sets the limit value of humidity and monitors the change rules of the temperature and humidity of the cultivation bed. When a humidity of a region is lower than the lower limit value, the water pump motor is controlled to supply liquid to the region. When the temperature in the cultivation bed is abnormal, the warning alarm is given, and the working parameters of the plate heater are regulated.
Summary

The design of this paper is based on the technology of aeroponics and takes the environmental factors which mainly affect the plant production as the core of design and monitoring. The visual interface is used to set, control and monitor the environmental monitoring of sensors. At the same time, the execution parts are controlled by PLC controller to realize the production of aeroponics in stable environment suitable for crop growth, accurately monitor and regulate the plant growth environment and optimize the plant growth environment, especially the root growth environment, further improve the automation and intelligence of the production system, create conditions for promoting the technology to achieve high-quality, high-efficiency and high-yield and be used for reference in the popularization and application of new and high technology projects in facility agriculture.

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