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Design of wireless transmission system for intelligent agricultural greenhouse data acquisition based on modbus communication protocol

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Abstract: Traditional agricultural greenhouses rely too much on manual labor and have a poor ability to adjust the key factors that affect crop growth, such as temperature, humidity, and illumination, resulting in low production efficiency and unstable product quality. Based on the MODBUS communication protocol, a set of intelligent agricultural greenhouse data acquisition wireless transmission systems is designed in this paper. Intelligent instruments, sensors, wireless transmission equipment, and smart control equipment (PLC) have been introduced in agricultural greenhouses. These sensors and instruments automatically collect data and wirelessly transmit it to the intelligent control system in the control room, which is located a few kilometers away. The intelligent control system processes the data and generates various control instructions which are then transmitted to the executive mechanism in agricultural greenhouses for implementation. We complete automatic adjustment of temperature, humidity, illuminance, and other parameters and operations. The intelligent, large-scale, and unmanned agricultural greenhouses are realized. It greatly improves the production efficiency and product quality of crops.

1. Introduction

Social science and technology are changing rapidly, and traditional agricultural greenhouses can no longer meet the requirements in scale, intelligence, and unmanned operations [1]. This wireless data acquisition and transmission system uses the MODBUS communication protocol. It includes sensors, intelligent instruments, wireless transmission equipment, and PLCs for intelligent control. The system is designed for agricultural greenhouses. It automatically collects data from various sensors and instruments in the greenhouse, then wirelessly transmits it to the intelligent control system in a control room located several kilometers away [2-3]. After receiving the data for processing, the intelligent control automatically issues all kinds of control instructions, which are transmitted to the executive mechanism in the agricultural greenhouse to complete the automatic adjustment of parameters such as temperature, humidity, illuminance, and operations. It greatly improves the production efficiency and product quality of crops.

2. Hardware design

In this design, the temperature and humidity sensor, illumination sensor, and intelligent instrument (digital voltmeter, digital ammeter) carrying MODBUS communication protocol can collect the temperature, humidity, illumination voltage, and current data of related equipment in multiple agricultural greenhouses in real-time [4-5]. The local LORA wireless transmission module in the agricultural greenhouse is transmitted to the LORA wireless transmission module in the control room several kilometers away. Then, the LORA wireless transmission module transmits the data to the PLC in the control room, and after data conversion processing, it is displayed on the human and machine [6]. The intelligent program's PLC will control the fan, water pump, lighting, ventilation, humidification, and auxiliary lighting functions in response to changes in data. This allows for the remote acquisition of agricultural greenhouse data and intelligent control, resulting in an environment that meets the needs of plant growth.

2.1. Intelligent instrument module design

The smart instrument used in this design is the AOB195U-9TY DC30V digital voltmeter and AOB195I-9TY DC5A digital ammeter, both of which have their own MODBUS standard communication protocol, as shown in Figure 1. This intelligent instrument is designed to be composed of two groups (a voltmeter and an ammeter for each group). One group of smart meters is installed in the agricultural greenhouse, which mainly monitors the electricity consumption of various sensors, fans, pumps, lighting, and other equipment. The other group is installed in the control room to monitor the power consumption of PLC, man-machine, and other control equipment. The data of the two groups of intelligent instruments are also transmitted to the PLC through the RS-485 bus for data conversion processing and display. Smart meter 1, 2 pin is connected to AC 220 V power supply. Smart meter 7, 8 pin INPUT receives the DC voltage/DC current (0 ~ 30 V/0 ~ 5 A). Smart meter 61, 62 pin is connected to RS-485 bus A, B line. The communication parameters are set as follows: the baud rate is set to 9600 bps, the communication format pAr is set to n8.1 (no parity, 8 data bits, one stop bit), and the communication address Adr is set to 2 ~ 247 (address 1 is occupied by the illumination sensor alone). This design uses two digital voltmeters and two digital ammeters, so the communication address is set to 2 (agricultural greenhouse voltmeter), 3 (agricultural greenhouse ammeter), 4 (control room voltmeter), and 5 (control room ammeter). Under the above communication parameter settings, we perform communication using MODBUS's standard communication protocol.

Figure 1. Smart instrument (digital voltmeter, digital ammeter), physical, wiring diagram.

2.2. Design of the wireless communication module

The wireless communication module adopts the LORA wireless transmission module, model F8L10T, two groups to complete the data interaction function. DC24V powers the LORA wireless transmission module. One is installed in the agricultural greenhouse and connected to the intelligent instrument and sensors through the RS-485 bus A and B lines. The other is installed in the control room and connected to the PLC data communication terminal. When the parameter is set, the baud rate is set at 9600 bps. ID and transmission addresses have different values, and the two paired LORA wireless transmission modules are opposite; for example, in LORA wireless transmission module A, ID is 0, and the transmission address is 1. Then, the LORA wireless transmission module B is 1, and the transmission address is 0. The working frequency should be set according to the allowable range. If there are multiple groups of LORA wireless transmission modules, the working frequency of each group should be distinguished. Through practice, we get the recommended interval of 1 MHz. The transmission power is generally set between 5 and 20 W. In principle, the farther the distance is, the greater the power is. In the city range, a group of LoRa wireless transmission modules can transmit a distance of 2 and 5 km, and if the transmission range is in the open area, the transmission range is larger.

2.3. Sensor module design
The core of this designed data acquisition system is light, temperature, and humidity sensors, which are equipped with MODBUS communication protocol, powered by DC24V, and installed in agricultural greenhouses to sample real-time data, as shown in Figure 2. The illumination sensor is HYDZ-GZD, and the temperature and humidity sensor is AW1485B. They are all connected to the LORA wireless trans transmission module A via the RS-485 bus A and line B (in parallel).

Figure 2. Illumination, temperature, and humidity sensor physical picture.

3. Software design

3.1. MODBUS communication programming
This design utilizes the MODBUS communication protocol to create an internal communication program within the PLC. The program polls multiple intelligent instruments, including digital voltmeters, digital ammeters, illumination sensors, temperature sensors, and humidity sensors. This allows for real-time collection of data from agricultural greenhouses, enabling monitoring, adjustment, and complete intelligent control.

To access each intelligent instrument and sensor and collect relevant data, it is necessary to build the data frame structure and read the instruction composition according to the requirements of the MODBUS protocol.

Table 1. MODBUS The protocol data frame structure.

Instrument, sensor	From the machine address	Function code	Data	CRC 16 calibration
Name	1 Bytes	1 Bytes	N Bytes	2 Bytes
Light sensor	01	03	00000002	C40B
Digital voltmeter 1	02	03	001d0001	143F
Digital current meter 1	03	03	001d0001	15EE
Digital voltmeter 2	04	03	001d0001	1459
Digital current meter 2	05	03	001d0001	1588
Temperature and humidity sensor	06	03	00000002	C5BC

The instruction in Table 1 consists of four parts: slave address, function code, data, and calibration. The slave address is the mailing address mentioned above. Function code 03 is the read-holding register to read the internal data of the instrument and sensor. The data part is divided into two sections. The first half is the address stored in the internal data of the instrument and sensor, and the second half is the number of bytes read. The calibration adopts MODBUS CRC16 calibration. In the debugging stage, we can detect whether all the intelligent meters and sensors work normally through the 485-turn USB interface and the computer serial port debugging assistant.

The communication protocol is written in four steps.

In Step 1, we create a subroutine named MODBUS.

The second step is the MODBUS communication program initialization setting (MBUS_CTRL instruction).

The third step is to set up the data reading program of the intelligent instrument and the sensor (MBUS _ MSG instruction), as shown in Figure 3.

The fourth step, the data processing procedure, is shown in Figure 4. This program part is divided into data conversion, processing, and operation.

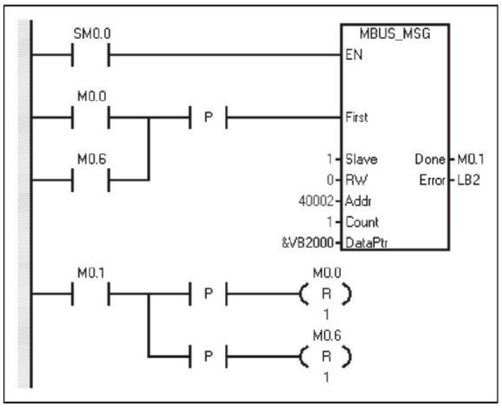

Figure 3. MODBUS data reading program (part of the program) diagram.

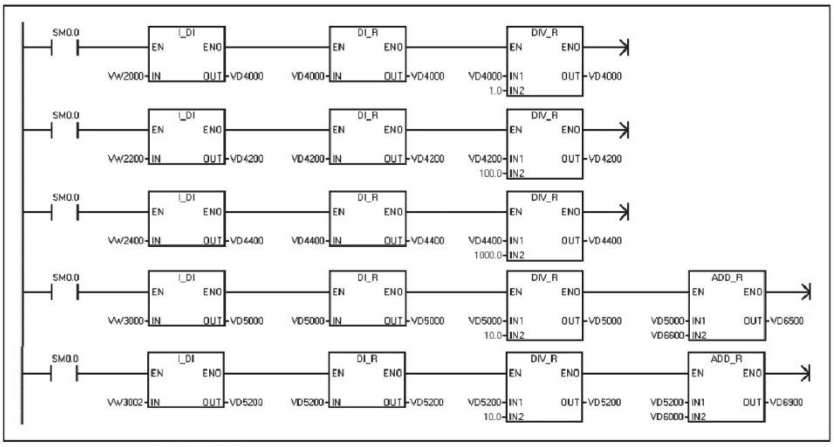

Figure 4. MODBUS data processor diagram.

3.2. PLC master programming

There are manual mode and automatic mode switching programs. To improve the convenience of manual and automatic mode switching, not only is the physical button set, but the virtual button M2.0 is set in the machine. When we press the manual mode (I0.0 or M2.0), the corresponding indicator light is on, and the operator can ventilate, humidify, and illuminate according to the temperature, humidity, and illumination at this time. When we press the automatic mode (I0.1 or M2.0), the corresponding indicator light is on, and the automatic program automatically adjusts according to the sensor transmission data. Since the manual and automatic modes are mutually exclusive conditions, the RS trigger is used in the programming. At the same time, edge triggers are used to prevent interference.

There are automatic alarm procedures for temperature, humidity, and illumination. In automatic mode, Q1.1 normally opens contact closes, and the comparison instruction compares the soil humidity VD6500 with the upper humidity limit VD6700 when the overwet alarm indicator is above the set humidity limit and the overdry alarm indicator is below VD6800. When the comparison instruction compares the soil temperature VD6900 with the upper-temperature limit VD6100, above the upper-temperature limit is set, and the high-temperature alarm indicator is on and below the lower temperature limit VD6300. When the illumination degree VD4000 is lower than the illumination degree set value VD7000, the M1.2 lamp indirectly controls the electrical coil to conduct auxiliary lighting.

Regarding sensor settings, the illumination sensor communication address is set to 1 by default. The address of the temperature and humidity sensor is set to 6, and both temperature and humidity data are read from the address during data transmission. PLC input adopts a 6-button combination button, including manual mode I0.0, automatic mode I0.1, manual lighting I0.2, manual alarm I0.3, manual fan I0.4, and manual pump I0.5. PLC output has six indicators (over wet alarm Q0.4, high-temperature alarm Q0.5, over dry alarm Q0.6, low-temperature alarm Q0.7, manual mode Q1.0, and self-actuating mode Q1.1), a separate flash alarm lamp with buzzer Q1.3, fan Q0.2, water pump Q0.0, and LED light Q1.2. There are four steps to writing a communication protocol.

4. Conclusion

Thanks to the MODBUS communication protocol and the data processing capability of intelligent control equipment (PLC), we can bring up to 247 slave stations and receive hundreds of sensor data so we can realize the intelligent, large-scale, and unmanned management of multiple agricultural greenhouses, and continue to improve production efficiency and product quality [7-8]. However, this design has some improvements, such as the slow data update rate when polling to access the slave station. In addition, the data transmission problem of more than 5 kilometers will be upgraded and improved in the future design.

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