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An Intelligent Greenhouse Control System

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Abstract

Because the greenhouse control systems designed in the past are not adaptable in practice, a new greenhouse control system based on RS485 bus is realized in this paper. A new smart sensor block is developed in the system to acquire field environment factor, which can reduce complex routing and increase reliability of the whole system. The model of solar greenhouse is introduced and fuzzy control is adopted in control unit. Besides, a friendly human-computer interface is developed by LabVIEW. The proposed system has been verified by the experiments in the control of medium single-span greenhouses.

Keywords*: single-span greenhouse, smart sensor block, fuzzy control, environment factor*

1. Introduction

As we Know, the plants living in the greenhouses can get rid of the climate and output more. Getting the environment under control by modern technology and equipment come the purpose of greenhouse environment control. Besides, greenhouse control system can reduce manual work, promote control precision and improve response speed. Auto-control is the tendency of artificial greenhouses [1-5]. In Netherlands, USA and Japan, precise greenhouse control has reached much high level. They have developed from single factor control to combination control. Nevertheless, until now, most of the greenhouse environment control systems are carried forward the structure of industry control and greenhouse control has its own specialty. It cannot just be transplanted from industry control systems. Compared with industry, agriculture production has a longer cycle with less return, and the operators are less educated. Therefore, it requires that the system is easily operated and costs less in constructing and maintaining [6-10]. Industry control technology is so mature that “the problem of applicability” comes to the key in greenhouse control [11, 12]. “The problem of applicability” determines whether greenhouse control can maintain healthy development [13]. In this paper, according to the medium single-span greenhouse, a new control system of much applicability for greenhouse is developed, and the smart sensor block comes one of the key designs of the system.

2. Sensor Block Design

There’re rarely specialized sensors for greenhouse environment control system on the market. High-performance transmitters for temperature, humidity, illumination intensity and CO2 density are of high cost and have to be installed respectively, which is not so desired for terminal users. In addition, digital sensor modules are of high cost and don’t share the same communication protocol standard. Under the circumstances, a new block of sensors is designed in this paper. Sensors of temperature, humidity, illumination intensity and CO2 density are put together in one circuit board, so that they can be installed at one time just with an aviation connector.

The humidity and temperature sensor uses SHT10. The communication of SHT10 applies I2C serial port, and it can be connected to I2C port of the DSP after isolation. TGS4161 made by FIGARO is chosen as CO2 sensor unit. The signal will be adjusted into standard current signal by specified circuit and transmit chip, and then delivered to the controller. The illumination sensor chooses a digital ambient light sensor BH1750FVI which is the most suitable IC to obtain ambient light data. Figure 1 is the hardware block diagram of the integrated smart sensor block. And TMS320F28035 is chosen as the main processing chip.

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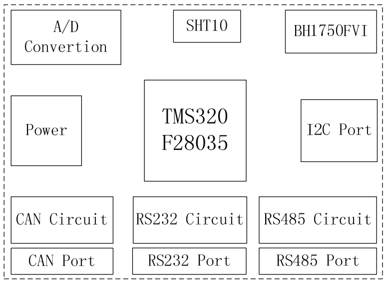

Figure 1. Smart Sensor Block

Using the idea of modular design, all the sensors are integrated in one module. The sensor module include power source, main chip, the sensors, A/D convert part, and several communication ports for expansion. By modular design, the routing from sensors to main control unit can be greatly simplified by communication bus such as I2C or RS485 etc. The main chip takes charge of measuring process. Besides of acquire the ambient environment data, the main chip also handle the acquired data to output unmistakable environment data. After calibration, the sensor system is accurate enough to content the whole system.

3. Structure and Hardware of the System

Greenhouse control is not that strict in real-time requirement because it is a kind of process control. Therefore, the system in this paper uses RS485 bus instead of field-bus, which reduces the requirement in communication for equipment. The system is similar to FCS in its functions. When normally run, control functions totally be accomplished by intelligent modules distributed in the field, data collecting and remote login are mainly fulfilled by the upper computer. If the upper computer or the communicating system stops working, the greenhouses still run normally, which guarantees the stability of the system.

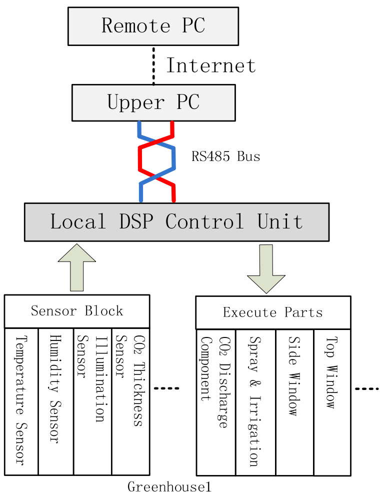

Figure 2. The Operation of the Proposed Dynamic Overmodulation

The global structure of the intelligent greenhouse control system is shown in Figure 2. A master control room is needed since greenhouse environment control system generally includes several or dozens of local control units. The upper computer takes charge of the coordination between the local units. Besides, the upper computer also collects the environment factors from local units and makes statistics for query and analysis in later days. In this way, the upper computer keeps mainly monitoring, secondarily controlling. The upper computer in master control room communicates with the local units (the lower computers) distributed in every greenhouse by RS485 differential half-duplex data bus. The local units respectively have environment factors collector (such as humidity and temperature sensors) and varieties of actuators (such as spraying, irrigation devices, heater and ventilator). Because every local unit can accomplish auto-control with its control algorithm, it doesn't need any control information from upper computer. Figure 3 shows the hardware structure of local DSP control unit. TMS320F28035 is adopted as the main chip of local unit.

The software in upper computer supports remote login. If the upper computer can connect to the internet, the users will enjoy controlling the greenhouses by remote.

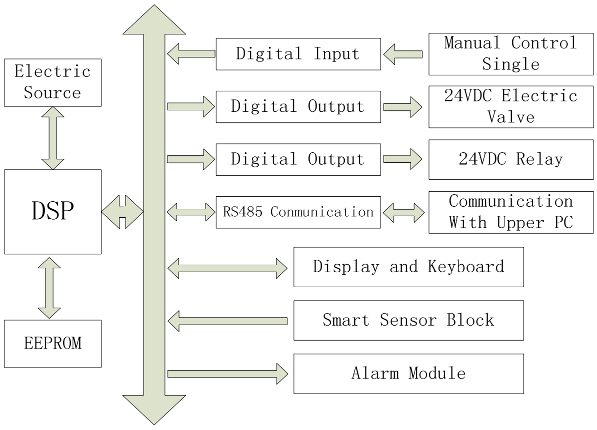

Figure 3. Hardware Structure of the Local Control Unit

4. Model of Single-span Solar Greenhouse and the Control Strategy

In the living cycle of most plants, the most important environment factors are temperature, humidity, illumination and carbon dioxide density. Temperature and humidity determines the living environment of the crops, while illumination and carbon dioxide density is closely related to the outputs. The four environment factors are synthetically controlled in this system. Obviously, traditional single factor control is not qualified in greenhouse environment control. In a microclimate of the greenhouse, all kinds of environment factors have coupling with each other. For instance, the coupling between temperature and humidity is most serious. While under different temperature and illumination, the demand of carbon dioxide isn't the same. Such kind of control demand cannot be solved by traditional control strategy.

The model of the greenhouse can be described in differential equation:

$$\dot{T}_{in}(t)=\frac{1}{K_1}[S_i(t)-\lambda Q_{spr}(t)]-\frac{\dot{V}(t)}{V}[T_{in}(t)-T_{out}(t)]-\frac{k}{K_1}[T_{in}(t)-T_{out}(t)] \quad (1)$$

$$\dot{W}_{in}(t)=\frac{1}{K_2}Q_{spr}(t)+\frac{1}{K_2}E(S_i(t),W_{in}(t))-\frac{\dot{V}(t)}{V}[W_{in}(t)-W_{out}(t)] \quad (2)$$

Where T_{in} and W_{in} are temperature and humidity in greenhouse, T_{out} and W_{out} are temperature and humidity outside the greenhouse, S_i the solar radiation, Q_{spr} the quantity of spraying, V the volume of ventilation, $E(S_i(t),W_{in}(t))$ the quantity of steam from transpiration. The rest symbols are constant parameters, and $E(S_i(t),W_{in}(t))$ can be simplified as follows:

$$E(S_i(t),W_{in}(t))=\alpha S_i(t)-\beta W_{in}(t) \quad (3)$$

The target greenhouses in this system are simple single-span solar greenhouses extensively used in south China. As a result, the heater and forced ventilation are omitted. The heat exchanges include solar radiation, spray, natural ventilation and heat conduction. Transfer function of temperature can be obtained after deduce and simplifying. It's first-order inertia with time lag [14]:

$$T_{in}(s) = \frac{Ke^{-\tau s}}{Ts+1} \tag{4}$$

The transfer function seems so simple, but the parameters are rough and fluctuating. So we adopt adaptive fuzzy controller in local control unit.

The control box diagram is showed in Figure 4, and Figure 5 shows software flow chart of local control unit.

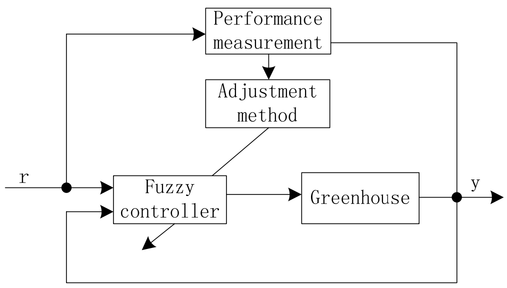

Figure 4. Control Box Diagram of Local Unit

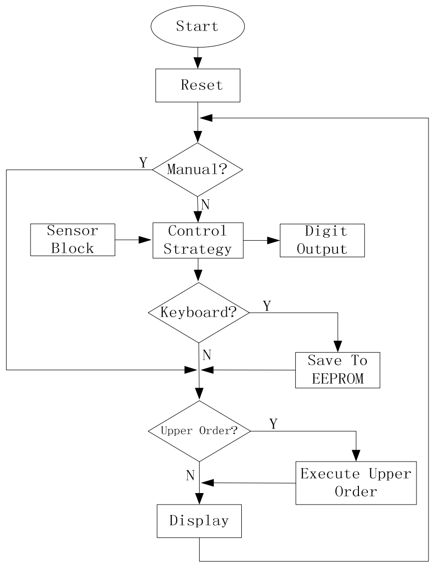

Figure 5. Flow chat of the local control unit

5. Experimental results

Figure 6 shows the performance of adaptive fuzzy controller and traditional PI controller in summer cooling. It can draw a conclusion from the graphs that natural ventilation and spraying are significantly effective in summer cooling.

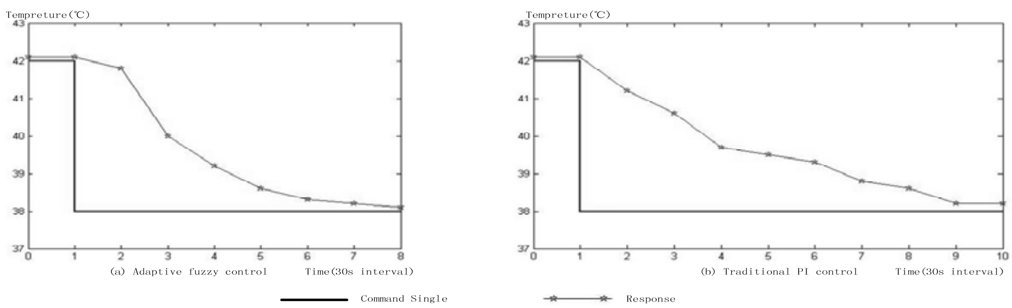

Figure 6. The performance of the controller

Traditional PI controller can follow the tracks of given single in a relative long time. Because of the adjustment of PI traditional controller, the actuators operate several times in second half time. The process is not wanted by terminal users, they hope the control operates like they themselves do, quick and set the matter at one go. Compared with traditional PI controller, adaptive fuzzy controller is quicker and less depended on accurate parameters. And operation frequencies of the actuators are much less, which is good for actuators and save energy without damage to control result. Therefore, fuzzy controller has its value in the practical application.

6. overall Advantages of the System

The target greenhouses of the system are the medium single-span solar greenhouse. This kind of greenhouses is of simple structure and the number of greenhouses within one system changes frequently. As a result, the stability and flexibility of the system needs to be promoted. In order to achieve this, proper investment in hardware is needed. For instance, the time control of spraying valve can be fulfilled by time relay instead of main control chip. This kind of investigation in hardware can also isolate auto-control and manual control thoroughly, which makes the system not obstruct manual control when system breakdown or extreme climate happens. Figure 7 is the photo of human machine interface, local control box and the working field.

Figure 7. Photo of the Human Machine Interface, Equipment and Working Field

Compared with former control system, the new greenhouse control system based on RS485 in this paper is more reliable and desired [15]. The advantages are shown as:

(1) Control signal is send out directly by field control units. When normally run, field controller units don't need any control signal from upper computer. When upper computer is broken down or halted, the controllers can work normally. The stability of the system is correspondingly promoted by enhancing its capacity of coping with problems.

(2) RS485 bus communication needs merely two wires, which simplifies the connecting and promotes the flexibility of building the system.

(3) Software and hardware functions are newly parted in the system, which reduces controller's burden and improves the system's reliability. All of these meet the operability demand of terminal users.

(4) By using a common PC as the upper computer and developing graphic interface on upper computer by LabVIEW, it reduces the complexity of building the system and cuts the cost.

7. Conclusion

In this paper, a greenhouse control system based on RS485 bus is developed. The system cuts investment in insignificant parts and improves stability of the system, which will be welcomed for terminal users after much has been done in applicability. The further research of this system will be focused on wireless low power consumption sensor system and optimization of control algorithm. Along with maturation and advancement of Zigbee, high-performance wireless remote greenhouse control system of low cost will be realized.

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