DNCS——A New Scheme for the Automation of Greenhouse Environment Control

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Abstract: To solve the problems emerged in the traditional computer control system in greenhouse, the present situation of the greenhouse environment control is analyzed and a new scheme of it is presented. By using distributed network control technology, the advanced single chip microcomputer (SCM) technology and humidity sensitive and temperature sensitive device which possess the ability of high precision and high reliability, an all digitalized "intelligent humidity-temperature sensor" and "double direction intelligent controller" was developed. The new developed greenhouse environment control was successfully used in several greenhouses in China. The future development of this system which can be used in livestock houses or other agricultural structures is also discussed.

Key words: greenhouse; automation of environmental control; distributed network control system
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1 Introduction

Greenhouse in china has been made a rapid progress over the past two decades, and the more advanced technology used in greenhouse environment control system will be anticipated. As the development of computer technology, computer data acquisition and control system which integrates computer, data acquisition, process control, network communication and CRT technology were used in industrial production widely. For information acquisition, handling, supervsing and production optimization, the system has the properties of easy to expend, friendly interface, and promising future. During the last decade, computer data acquisition and control system has been widely used in the sicentific research and production in agriculture. Developing from the single element, single goal, static management to multi-elements, multi-goals, and multi-levels, is one of the important research direction in agriculture by using advanced technologies.

2 Present Situation Abroad and at Home

With the development of computer technology, the agricultural application of electronic technology, intelligent sensor technology, mechanical-electrical integration, computer network technology, the greenhouse system has become the frontier science of research field to enhance the competitiveness of agricultural production in the world market, scientifically utilize the agricultural resources, increase the agricultural production, decrease the production cost and protecting the environment since 1990s. Agriculture in developed countries has reached a relatively high level of industrialization and many countries in the world have increased the technical investment in greenhouse to get more agriculture production shares in the world market.

Micro-electronic technology and computer network management were widely researched and utilized in greenhouses (or livestock houses) environment control and daily operation and management in developed countries, especially in Netherlands, Japan, USA, Israel and Germany, where the limitation of human control was overcome.

The greenhouse has been developed rapidly for over 20 years in China and the acreage of greenhouses is the largest in the world. During "the Ninth Five-Year Plan" period, the efficient and energy saving sloar greenhouse, multi-span and the successful double layer inflated plastic multi-span greenhouse which suits for northern China have greatly reduced the energy consumption compared with the same products in foreign countries. All the researches played an important role in leading our agriculture from traditional, labor intensive management to modern integrated effective management. However, the greenhouse in China is far from the industrialized agriculture and there are still many problems in this field such as the poor integration of the greenhouse

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equipment and industrialization, and environment control approach, hard to share the hardware and software and poor reliability, etc.

Environment control is the key technology in greenhouse production. In China, the SCM (single chip microcomputer) based intelligent control system in greenhouse was developed by some institutes and put into production in experimental scale. However, this kind of computer control system has almost the same hardware and just peforms the analog signals and I/O flow of on-off signals. This research optimized the whole system which fully utilizes the computer power, and presents a new scheme for the greenhouse environment control-distributed network control system (DNCS).

3 Scheme of the DNCS

In order to overcome the disadvantages of complexity, inconvenient repairing and high price resulted from the traditional central computer control, and with the aid of advanced SCM technique and high precision, high reliability humidity sensitive and temperature sensitive device, the advanced digitalized "intelligent temperature-humidity sensors and controller" and the DNCS were developed. Computer data processing technology and computer network communication technology was used. The great functions of SCM was fully utilized in the measurement and transmission part of sensors, and the physical information can be digitalized directly which will save the analogy device such as A/D adapter and amplifier. The reliability and precision of the sensors were greatly improved while the material cost of the humidity and temperature sensors was decreased consequently. The RS-485 communication protocol was applied in practical connecting of sensors, which allows utmost 256 sensors in one data wire. In addition, there are still other advantages of RS-485 protocol such as good ability in noise-resistance which benefits from the circular current communication style, high reliability on data exchanging, long distance data transmission and low cost of cable lines. This scheme was developed on the basis of market analysis and long-term investigation abroad and at home. The scheme of DNCS is shown in Fig. 1, from which three obvious characteristics of DNCS can be found: object-oriented and distributed structure, intelligent unit integrating supervising and protection, and RS-485 field bus network.

3.1 Object-Oriented and Distributed Structure

Since the computer was used in greenhouse, the development of a control system has experienced with two stages: central control system and distributed control system.

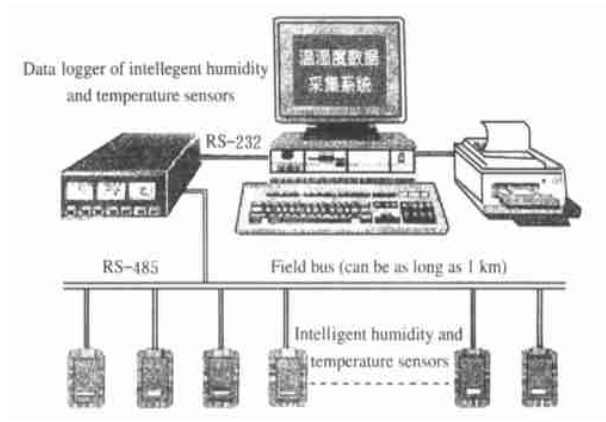

Fig. 1 The scheme of the DNCS

3.1.1 Structure of central control system

The central control system has the structure which centralized the units of measurement, protection, control and communication into one central computer. The system consists of upper computers which perform the function of data processing, displaying and telecommunicating, and local devices which accomplish the function of data input and output, control protection and supervision.

There are several drawbacks in this structure: the local devices will be an information "bottleneck" due to performing too many functions and the reliability of the system is relatively low, and when there are malfunctions in local devices, all local and teledata will be lost and hence the whole system collapsed. In addition, it is difficult to design and expand with high resource-consuming.

3.1.2 Structure of distributed control system

The distributed system also consisted of two levels: the upper level is used to manage the system and the lower level which consisted of many independent functional units does the rest. There are two types of distributed system according to the different uses of functional units.

1) Function-oriented distributed system

Each unit performs only one function and the function of the system can be divided into temperature measurement unit, humidity measurement unit, remote control and operation unit, data acquisition unit, protection unit, etc. The advantage of this system is that the functional units and communication cable was separated completely in electronics. Any units do not influence on other units. While its drawbacks are the relatively complexity of the second

connection, difficult to expand and the units can not be installed separately.

2) Object-oriented distributed system

One unit connects with one object which can be treated as input line, output line, sensors and contactors. This kind of system can be called real distributed greenhouse environment control system, as it can break the function limitation of second equipment and former management system. This system is in accordance with the technical standards of IEEE and will be the direction of future development. The followings are the characteristics of this system: 1) High reliability: the malfunction of some units will not influence the operation of the whole system; 2) Independence between the units and little influence on each other; 3) Good ability in data sharing; 4) High efficiency of the system; 5) The multifunction and integration control, easy to maintain and operate; 6) Good ability in noise-resistance; 7) Easy to expand; 8) Low cost because much less cable is needed.

The fundamental difference between DNCS and the common analog device is that the function of the DNCS should be accomplished by software. That means that in order to meet different practical needs, not only the high quality hardware but also the compatible software are needed. The quality of the DNCS is directly related to the function of the software.

The DNCS software which combines with the standard control strategy and advanced control approach was developed. The fuzzy control strategy is also used in this system and consequently, the interchangeability of the DNCS was improved.

3.2 Field Bus

Field bus is the basic part in the communication system which requires the intelligent sensors.

Except for the transducer, other local sensors such as humidity and temperature sensors, liquid-level sensors, wind speed sensors and valves have some extent of intelligence. This is an entirely different revolutionary change to the conventional analog device. The double direction multi variants digital communication was realized between the sensors and the upper level control units. The digital units take the place of 4~20 mA analog signal standard, which was used for a long time. Field bus is the result of the development of various technologies such as electronic technology, instrument technology, computer technology and network.

Since the field bus is utilized, the control circuit has been downloaded in the lower level, and distributed in the local instruments, which saved many pieces of connection and transformation equipment and hence the number of the hardware items was reduced and the cost of the system was also decreased. In addition, the different sensors can be easily connected in the cable, be convenient to the future repairing.

The most striking advantage of the field bus is that it downloads the control functions to the local device. Most tasks are accomplished by the local controllers, which entirely change the traditional strategy that needs central computers to perform all functions. So it is possible to construct a powerful opened control system that can realize the information and equipment sharing.

Other advantages of the field bus can be summarized as follows: 1) Eliminating the information bottleneck due to the 4~20 mA signal transmission; 2) Reducing the number of lines used for connection, saving the A/D or D/A converter; 3) High precision in measurement; 4) High reliability and real time ability; 5) The function of the converter is enhanced and the number of sensors is reduced; 6) Easy to repair and long service life.

3.3 Intelligent Units-Integration of Supervision and Protection

The intelligent units include intelligent temperature-humidity sensors, intelligent temperature-humidity controllers and intelligent wind speed sensors. The functions and characteristics are presented as follows:

3.3.1 Characteristics

1) Integration of supervising and protection: not only guarantee the measurement precision, but also improve the reliability of the system.

2) Standardized hardware: the hardware in each unit is the same while the software is different. The same kind of template can be exchanged while the precision is not influenced.

3) Object oriented design.

4) Powerful function and a wide range of adaptive, various protection approach can be flexibly implanted or removed.

5) A strong capability in noise-resistance.

6) Convenient LCD display.

7) Self-detection and power off protection.

3.3.2 Function of the integration units

1) Providing various kinds of protection approaches.

2) Parameters can be calibrated in local units.

3) Providing various kinds of status information and operation functions.

4) Several kinds of alarm functions for abnormal

situations.

5) Parameters adjustment.

6) Providing the communication interface between the network and digital data.

4 Prospective of the Automation of the Greenhouse Environment Control

The market of the automation of the greenhouse environment control is promising. In addition, the design standard of the automation of greenhouse environment control in China has not been released, therefore, the competition in automation of greenhouse environment control will be fierce within the recent few years. How the automation of greenhouse environment control will develop in the future is the most concern for every engineer who engages in automation of greenhouse environment control. The followings are some points of view:

4.1 Intelligent Sensors and Devices

Intelligent sensors and devices are based on electronic technology. Large-scale integration circuit and embedded system made it possible to integrate the functional CPU, A/D adapter and input-output device into one chip in SCM. With the device shell and connection line, a full function intelligent device can be made. This device can perform multifunction such as signal transmission and processing, data processing and exchange, and computing the predefined program.

RS-485 serial interface and field bus network were used in communication. Using field bus network, intelligent sensors and controllers, and personal computer, a small scale DNCS can be made, which will be better than the traditional DNCS. Intelligent I/O template connected by field bus, local equipment and intelligent device made up of the further scattered distributed control station and hence formulate the new structure of DNCS which consists of three levels: control network, system network and management network.

The I/O module is located in the low level, equipment and intelligent devices can all be operated independently and can perform the function of error detection, data processing and transmission, computation for control strategy, alarming and self-diagnosis. Each intelligent unit is not entirely dependent on the central computer, even if the central computer is in malfunction, each unit can perform independently and execute the predefined task.

4.2 Combination of First Device and Second Device

In the present development of the greenhouse environment control system, the functional units and the local device are separated in all kinds of systems. This situation leads to the sophisticated installing of electrical cable line, and will increase the difficulty on construction and fiancial balance. To resolve this problem, the first device manufacturer should do a lot of work to integrate the sensors and micro processing chip into first device, which will pave the way for local control strategy. There will be still a long way to go before all the first devices are intelligent. Anyway, the intelligent device represents the direction of the future development.

4.3 From Local Communication to Advanced Field Bus

According to the standard of international electronic committee and the definition of the Field Bus Foundation, field bus is the communication network which connects the intelligent local devices and automatic equipment.

As the emergence of the intelligent local devices and the release of the standard of high level filed bus, it will be possible to realize the automatic control of greenhouse environment by using standard field bus control system.

4.4 Integration of Supervising and Protection

The greenhouse environment control system developed by our institute has been used in several multi-span greenhouses in China, such as in Yantai Academy of Agricultural Science, Anyang Vegetable Research Center.

As the market economy matures, the industrialized agriculture management reforms and the market regulation is enforced, it is believed that the DNCS can be used not only in greenhouses, but also in livestock houses or other agricultural structures in the future.

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分布式网络控制——实现温室环境调控自动化的一种新方案

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摘 要: 针对传统计算机控制技术在温室环境调控中呈现的控制复杂、维修不便和价格昂贵的缺点, 该文分析了温室环境调控自动化的现状, 提出了一种全新的实现方案。采用分布式网络控制技术并使用国际先进的微型单片机技术和国外高精度、高稳定性的湿敏及温敏器件, 研制出全数字化"智能温湿度传感器"和"双回路智能温湿度控制器"。目前研制的温室环境调控自动化系统已在国内数家现代化智能温室推广应用。还对温室环境调控自动化的发展提出了几点看法。

关键词: 温室; 环境调控自动化; 分布式网络控制系统