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CONTROLLING A GREENHOUSE PRODUCTION PROCESSES AND ENVIRONMENT

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ABSTRACT
Greenhouse production is most energy consuming branch in agriculture. In controlling production processes and very dynamic greenhouse environment, producers are faced with high cost of operations and high energy inputs. In order to make this production system more energy efficient, precise control of environment and production processes is needed.
This paper presents an overview of possibilities and importance of good control. The types of control equipment and installation considerations are presented. The paper gives the most important attributes of a controlling system that need to be fulfilled in order to have constant and reliable control. The explanation of levels of controlling and the possibilities of controlling irrigation and nutrition processes, which are of great importance for plant production, are also presented.
KEY WORDS:
greenhouse, energy, control, environment, processes, irrigation, equipment

1. INTRODUCTION

Greenhouse is a very complex and intensive agricultural production system. It is intensive in.terms of production, energy consumption, labor and cost. Environmental control systems affect all this areas.

Early control systems include simple pulling a chain in order to open or close a vent, turning a valve for controlling heat or irrigation etc. After this, also laborious and less precise procedures, independent thermostats, humidistat and timers were introduced.

Problems with controlling several independent timers lead to development of electronic analog controls known as a "step" controls. These controls significally improved controlling processes by combining the functions of several thermostats into a single unit with a single temperature sensor.

Today, computerized control systems are basic for intensive greenhouse production system.

2. IMPORTANCE OF GOOD CONTROL

Problem in greenhouse climate control is that temperature changes occur rapidly and are depending on solar radiation, outside temperature, relative humidity and production systems. These changes affect the overall energy efficiency of greenhouse production systems. The aim of every producer is to reduce the energy input per unit of production, and maintain and increase the quality of final product.

Accurate controlling systems and their coordination can reduce direct energy inputs enclosed in fuel and electricity for heating. Automated controls increase the productivity of workers enabling them to attend to more important tasks. This can improve the overall energy efficiency of greenhouse system.

The most important function of good controlling system is the information available to the grower that can be used in terms of better management decisions. Growers report reduction of overall water use as much as 70% if operating with good controlling equipment. In terms of water management significant savings were obtained in fertilizer application and its effectiveness.

More precise control of temperature and relative humidity helps in minimizing plant stress and diseases reducing the need for fungicides and other chemicals. Advantages of good climatic control can be seen in healthier plants, less susceptible to diseases and insects. In terms of technical systems and equipment, good control prevents over-cycling of equipment and increasing of its operating hours.

Concerning the fact that greenhouse system is a very complex and dynamic environment, even a small percentage of improvement in several areas will yield in overall improvements.

3. LEVELS OF CONTROL

Greenhouse control system is designed as a production tool that facilitates growing processes. So it is obvious that capabilities of a greenhouse control system are more than controlling an air temperature or relative humidity. It is a kind of direct process control of biological growth parameters. Controlling systems are developed with programs and software for operating specialized equipment (fog systems, CO2 enrichment, shading, roof vents, irrigation, nutrition etc.).

There are three levels of control requirements that need to be considered for every greenhouse zone.

Equipment level

Equipment level refers to controlling of individual equipment or devices that control or interface with a single type of equipment. These can include motor controls for controlling vent openings, motor starters for pumps, fans, etc.

Function level

This refers to control of all equipment for a particular function such as temperature management, irrigation or nutrition. Individual controllers can be electronic (analog step controllers) or microprocessor based controllers.

System level

This refers to controlling of all equipment, functions and systems. The operation of each piece of equipment is effected by the operation of other piece and changes with the climatic conditions. A single piece of equipment often performs more than one task (heaters can serve both for heating and dehumidifying) and these tasks can occur at the same time. So it is of great importance to have a fully integrated system level control that can bring all of the systems in greenhouse together in to a single well-coordinated system.

When reviewing the control needs of a single greenhouse production system, it is important to consider all elements of environment management, not just heating and cooling. Everything should be considered, nutrition and irrigation systems, even if there is no need for them at the moment. All of these systems are independent. They may affect or be affected by the other functions, so controlling them in an integrated mater is of great importance. Beside temperature and humidity, one should consider CO2 management, lighting, irrigation, nutrition control, chemical treatment, heat storage systems and shade curtain systems.

Even the very best control systems can't make the greenhouse production system perform beyond the limitation of the equipment in the greenhouse. A poorly engineered climate zone will yield poor results or in best case will be difficult to control. So it is of great importance that, when building a new greenhouse, control manufacturer is involved providing the processes of heating, cooling, irrigation and nutrition with proper controlling systems.

4. TYPES OF CONTROL EQUIPMENT

There are four types of controls available:

- thermostats and timers analog "step"
- controllers computer zone controllers - integrated computer controllers

Thermostats and timers

Thermostats and timers are simple and low cost devices that provide limited control. Thermostats allow manual adjustment of on/off settings. Timers are used as on/off switches. For example, photoperiodic lights were turned on and off during night by timers.

Apart from being inexpensive and simple to install, there is a little if any benefit. They provide very limited control, no coordination between equipment and function, poor accuracy and poor energy efficiency. The increased energy consumption and the effects of lost in production due to poor control far exceed savings from their lower initial costs.

Step controllers

The name "step" controller has an origin from the ability to step the control in multiple stages. Step controllers car receive signals from two ore more sensors (temperature, relative humidity, light). Sensors can be placed among the plants. Their number is limited and the type is predetermined in the step controller purchased. A temperature-sensing step controller can't be used for wind or CO2 sensing.

The main disadvantage is the basis that is on/off control. Even< with multiple stages, greenhouse climate is always 1° C above or below the desired level. The other disadvantage is their dedication to the tasks for which they are purchased. Sensors must be replaced or restructured when it is necessary to perform a different task.

Computer Zone controllers

These devices can figure as simple, limited computers. Microprocessors (fig. 1) usually have a keypad and two- or three-line LCD display. Generally they don't have a floppy disk drive. Concerning the number of output connections (sometimes more than 20) it is cheaper to use microprocessors than several step controllers.

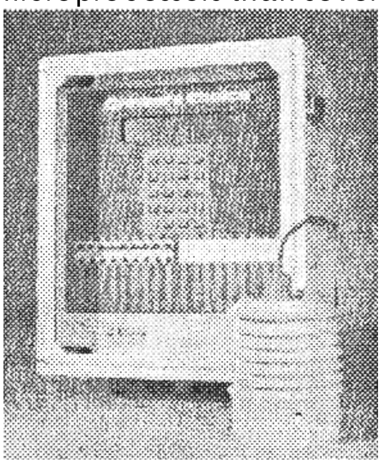

Figure 1. Microprocessor used for controlling heating, cooling and relative humidity

With microprocessors it is possible to integrate a range of devices for measuring few parameters at the same time. Their accuracy is quite good. They can be used with wind direction and speed sensors, or rain, in order to give a signal for closing the vent openings. CO_2 generators can also be controlled with microprocessors that can be set to activate generator when light intensity exceeds a given set point.

Using microprocessors can improve energy efficiency, provide less wear of the equipment and enable more uniform temperature control.

Integrated Computer Control (ICC)

In this system a single computer controls all equipment in a climate zone, by using all available sensors (temperature, relative humidity, CO2, light, water content of soil and air). The ventilation is influenced and thus controlled in relation with temperature, solar radiation, wind speed, wind direction and rain. The result of applying an ICC is a stable and accurate climate with oscillations of temperature of 0.5° C, energy conservation and improved product quality.

The central computer can operate under two different plans. The first option (fig. 2) is that the crop manager programs set points, such as heating and cooling temperatures, and relative humidity into the computer. Computer receives input signals from sensors in each greenhouse zone, integrates them and decides what is the equipment that needs to be activated in order to reach the desired set points. When decision is made computer sends output signals to the equipment in each zone.

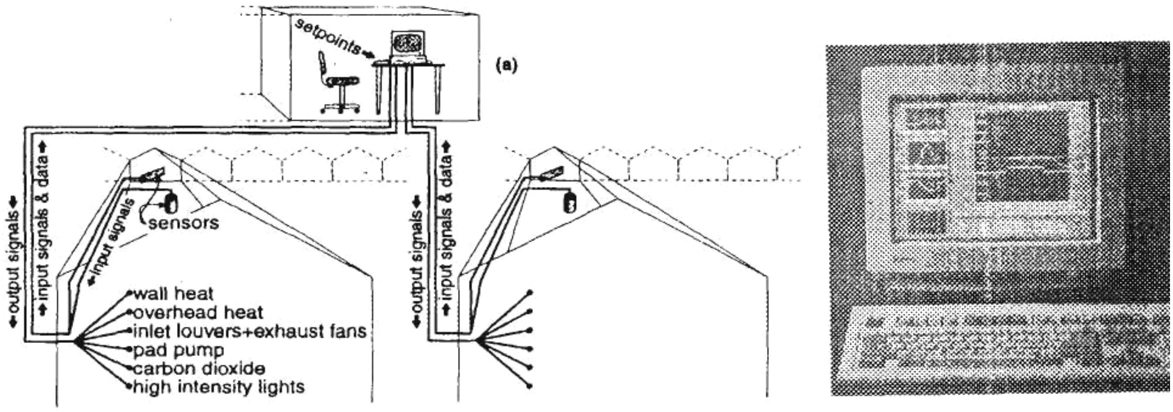

Figure 2. a) Schematic plan of integration of computer into the control system;

b) Control computer operating under this scheme

The second option is that production manager again programs set points into the computer. Within each greenhouse zone is a controller, which can range, in complexity, from the microprocessor to computer. The computer sends set points to the controllers. Each controller then receives input signals from sensors within greenhouse in which the controller is located. These signals are integrated in the controller, and output signals are sent to the equipment.

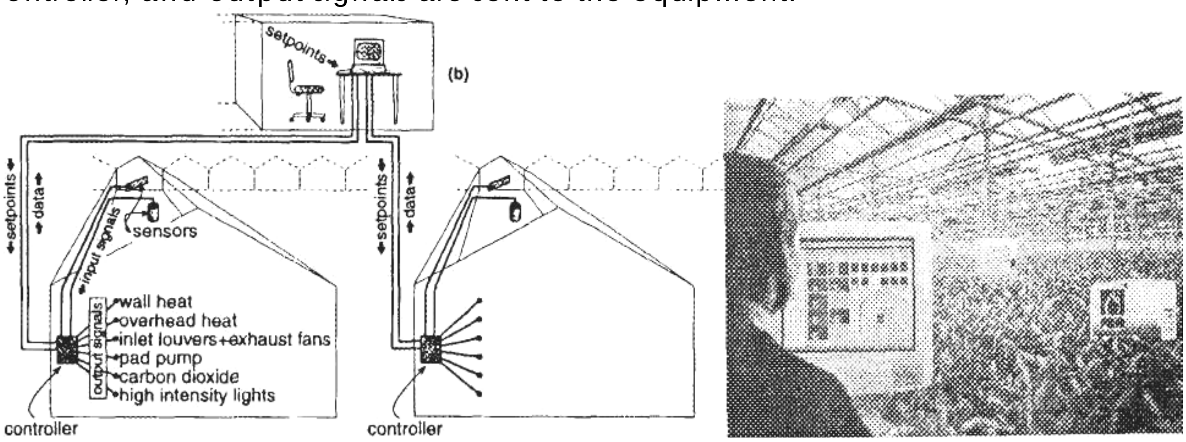

Figure 3. a) Schematic plan of integration of computer into the control system b) Computer system operating under this scheme

Systems under the control of central computer have a several capabilities that are very limited in dedicated microprocessor systems typically found in greenhouses. These advantages include data logging, data plotting and expandability.

Data form each sensor including inside and outside temperature, relative humidity etc., can be stored in the computer for evaluating the efficiency of various pieces of equipments and future decision-making. There is a possibility to tabulate or graphically plot these records for easier analyzing.

Dedicated microprocessors usually have a set number of output connections and are even limited to specific control functions such as temperature or irrigation. When more controlling equipment is installed in a greenhouse, more microprocessors must be purchased. Each of these is independently managed. This can be very complicated for managing and can lead to a very costly computer system that can cover and coordinate total greenhouse range. When new generation of microprocessor is developed, producers often need to replace existing microprocessors. The computer system has an advantage because it can be more easily "updated" by simple changing the software.

5. CONTROL REQUIREMENTS

There are four main attributes of controlling a greenhouse system that need to be fulfilled in order to achieve all the benefits of good control.

Stability is the guarantee that system will be able to follow an input command System is unstable if its ojjtput is out of control or increases without bound. There are many mathematical procedures that can help in predicting an unstable period of system thus enabling a producer to react on a proper way.

Accuracy of the system is its output ability to achieve the desired input or to "track" the input within a reasonable error margin. En example of typical response to a "step" input (reaction to a sudden change) is shown on the figure 4. When the change is made, for example in temperature, there is a period required for the temperature to respon7d. The temperature may cross the setting point and then oscillate for a period (setting time).

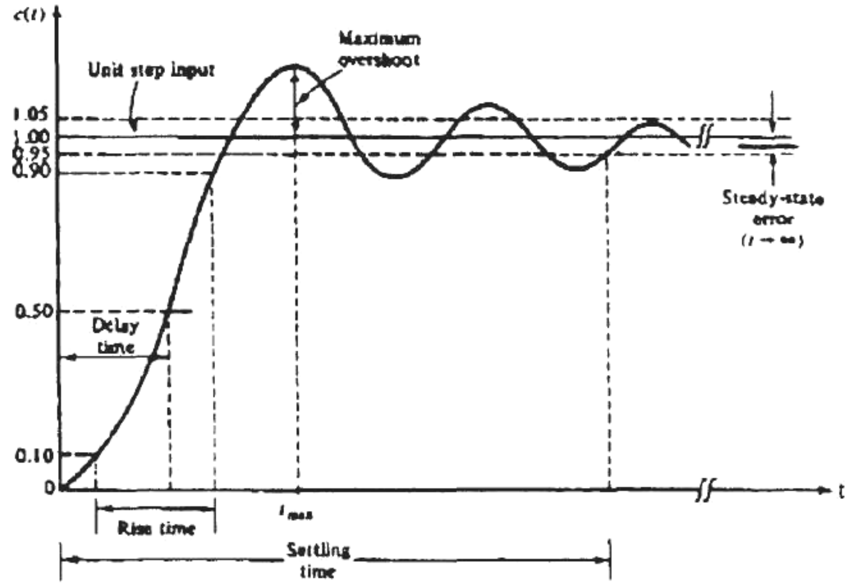

Figure 4. Typical response of a control system to a change in input

The most desired situation is immediate response with no oscillations and no error but this is almost impossible. There are errors in the measuring devices, in sensors and in converters. In the control theory there are computer means to access error or to predict its significance.

For measuring instruments, sensitivity shows the smallest change in the parameter being measured. Beside sensors, other parts of the system can change over time. For example, the output of a sensor in greenhouse may be sensitive to related environmental parameters. In good controlling system the output should be insensitive to tinese changes.

Overall, present hardware of computer systems are extremely reliable. Hard discs eventually wear out but it is a much longer period then period needed for wearing out ventilators, relays or motors. The reliability of software can be a serious problem Another problem may occur with interference of system programs with other program or users (Internet, viruses, hackers).

6. IRRIGATION AND NUTRITION CONTROL

The quantity of water that is needed depends on production technology, plant species and growth stage. When determinating amount of water, producer needs to consider the ability of plant water intake, the fact that it is easier for plant to take water in early morning hours than during the day, and the temperature of water. So, this is one of the most complex areas fro producer to project the control system. Figure 5 gives an overview of possibilities for irrigation decision making.

Greenhouse nutrition is much different from other application in agriculture. Plant growth is forced through out the year under intensive condition. Volume of root substrate is minimal and has no lover horizon as in the field and there is no possibility for plant roots to "catch" nutrients from dipper horizons.

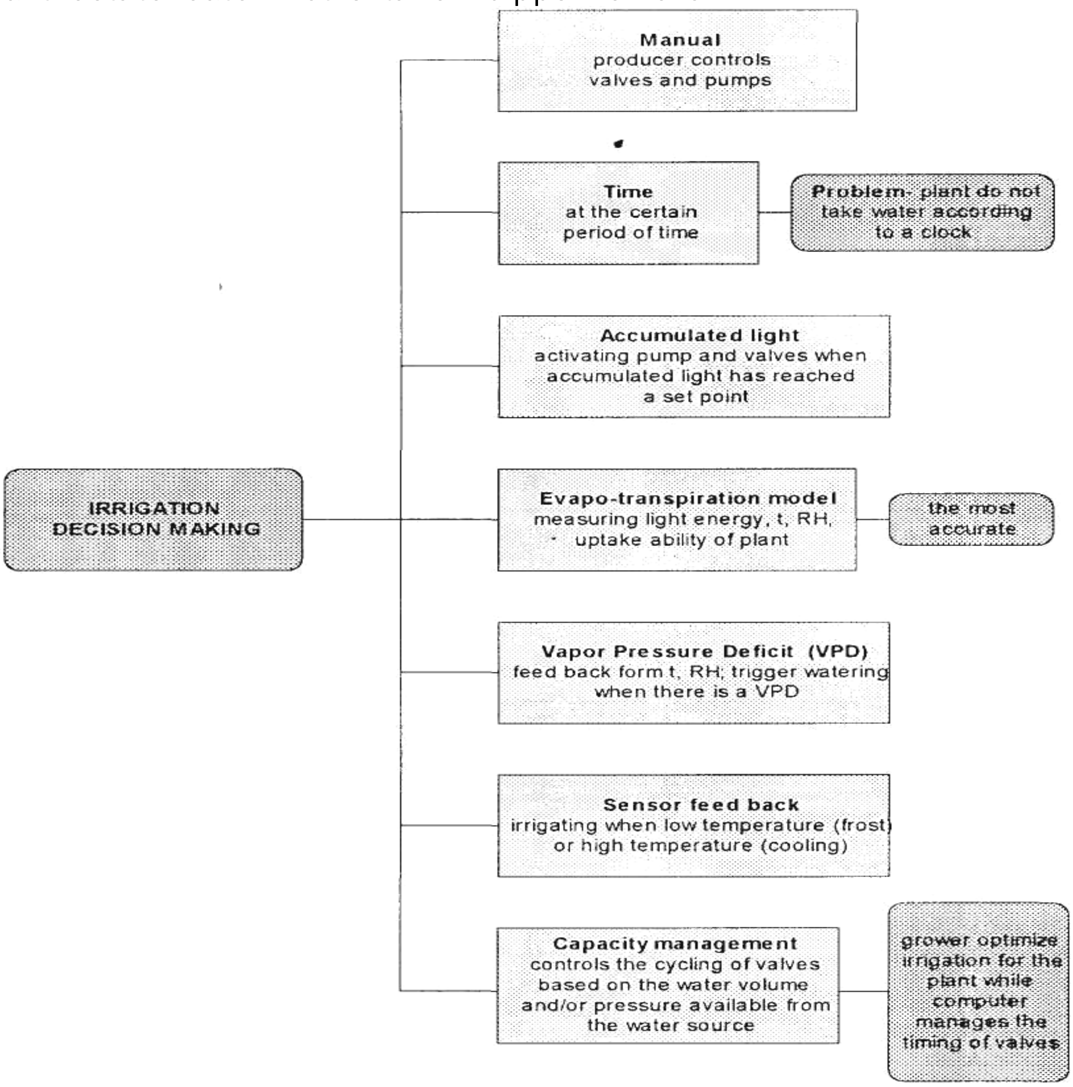

Figure 5. Possibilities of irrigation decision making

When calculating the amount and the type of fertilizer needed producer should consider plant species, stage of growth and type of root substrate.

In greenhouse production systems application of fertilizers is mostly integrated with irrigation systems (fertigation system). Controlling of fertilizer application is thus influenced by irrigation control systems.

7. CONCLUSIONS

Greenhouse production system is the most complex and most intensive agricultural production system. Plant growth is forced through out the year with expectation that it will yield a good, healthy product in certain quantities. Much of the work and energy is embodied in this product so no mistakes should occur during the production cycle. In order to minimize mistakes and maximize the profit, precise control of greenhouse production system is needed.

The most inexpensive and the simplest to install are the thermostats but these are their only advantages. Step controllers were introduced after and are still present as parts of Integrated Computer Control. ICC presents the most reliable controlling system that provides integrated control for numerous greenhouse climate zones providing the producer with useful data for further improvement in production technology.

Regardless to controlling system chosen it needs to be stable, accurate, insensitive to changes and extremely reliable.

As for the controlling production processes, irrigation and nutrition are most important. Integration of these two processes can improve overall energy efficiency and reduce labor input, but it requires a complex controlling system based on time and quantity of fertilizer application. Decision for irrigating can be made manually, time based, according to accumulated light, evapo-transpiration model, VPD or with sensor feed back. There are reports from the growers that reduction of overall water use is as much as 70% if operating with good controlling.

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