DOI: 10.26565/2304-6201-2020-47-08

УДК 681.5.01

Model of process control system in greenhouse agro-industrial complex

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The model of an automated control system for microclimatic indicators and energy consumption of greenhouses has been developed. To design intelligent components and on their basis to synthesize adaptive computer systems for managing the microclimate and energy efficiency of greenhouses is an urgent problem. The purpose of the work is to analyze greenhouse management modes, to make comparative characteristic of the process automation systems, to develop an information scheme of greenhouse-environment interaction, as well as, a structural scheme of greenhouse microclimate control, to select modern technologies to implement automatic climate control systems and to analyze the capabilities of the developed control model of a technological process. The research methods are based on the basic principles of the theory of heat and mass transfer using modern elements of computerized control. The structure of the greenhouse microclimate control system with a variable composition of equipment that provides rapid adaptation to the management requirements of a particular greenhouse has been developed. It has been proposed to develop the components and the structure of a greenhouse microclimate control system with implementation of the comprehensive approach, which includes communication and information management systems and technologies, a modern element base, the Android software, decision support tools. This approach is based on the following principles: consistency, variability of the equipment composition, openness, modularity, and usage of a set of basic design solutions. The microcontroller is the central control device of the entire control system. An availability graph of the client-server communication for the greenhouse microclimate control system, which has two final states, has been developed.

Keywords: *microclimate, greenhouse, control, automatic control system, microprocessor, hardware, element base.*

Модель системи управління технологічним процесом в тепличному агропромисловому комплексі

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Розробка моделі автоматизованої системи управління мікроклиматичними показниками і енергоспоживанням тепличного господарства. Актуальною проблемою є проектування інтелектуальних компонентів та синтез на їх основі адаптивних комп’ютерних систем управління мікрокліматом та енергоефективністю тепличного господарства. Метою роботи є аналіз методів управління режимами роботи тепличного господарства, порівняльна характеристика засобів автоматизації управління технологічним процесом, розробка схеми інформаційної взаємодії теплиці з оточенням та структурної схеми управління мікрокліматом теплиці, підбір сучасних технічних засобів реалізації систем автоматичного регулювання мікроклімату та дослідження можливостей розробленої моделі управління технологічним процесом. Методи досліджень ґрунтуються на основних положеннях теорії тепло- і масообміну з використанням сучасних елементів комп'ютеризованого управління. Розроблено структуру системи управління мікрокліматом у теплиці, яка має змінний склад обладнання, що забезпечує швидку адаптацію до вимог управління для конкретної теплиці. Запропоновано розробляти компоненти і синтезувати структуру системи управління мікрокліматом теплиці здійснювати за комплексним підходом, який охоплює комунікаційні та інформаційно-управляючі системи та технології, сучасну елементну базу, програмне забезпечення з використанням ОС Android, засоби підтримки прийняття рішень і ґрунтується на таких принципах: системності, змінного складу обладнання, відкритості, модульності та використання комплексу базових проектних рішень. Мікроконтролер є центральним управляючим пристроєм всієї системи управління. Розроблено граф досяжності для комунікації між клієнтом та сервером для системи управління мікрокліматом теплиці,який має два кінцеві стани.

Ключові слова: мікроклімат, теплиця, управління, автоматична система управління, мікропроцесор, апаратне забезпечення, елементна база.

Модель системы управления технологическим процессом в тепличном комплексе

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Разработка модели автоматизированной системы управления микроклиматическими показателями и энергопотреблением тепличного хозяйства. Актуальной проблемой является проектирование интеллектуальных компонентов и синтез на их основе адаптивных компьютерных систем управления микроклиматом и энергоэффективностью тепличного хозяйства. Целью работы является анализ методов управления режимами работы тепличного хозяйства, сравнительная характеристика средств автоматизации управления технологическим процессом, разработка схемы информационного взаимодействия теплицы с окружающими и структурной схемы управления микроклиматом теплицы, подбор современных технических средств реализации систем автоматического регулирования микроклимата и исследования возможностей разработанной модели управления технологическим процессом. Методы исследований основываются на основных положениях теории тепло- и массообмена с использованием современных элементов компьютеризированного управления. Разработана структура системы управления микроклиматом в теплице, которая имеет переменный состав оборудования, обеспечивает быструю адаптацию к требованиям управления для конкретной теплицы. Предложено разрабатывать компоненты и синтезировать структуру системы управления микроклиматом теплицы осуществлять с комплексным подходом, который охватывает коммуникационные и информационно-управляющие системы и технологии, современную элементную базу, программное обеспечение с использованием ОС Android, средства поддержки принятия решений и основывается на следующих принципах: системности, переменного состав оборудования, открытости, модульности и использования комплекса базовых проектных решений. Микроконтроллер является центральным управляющим устройством всей системы управления. Разработан граф досягаемости для коммуникации между клиентом и сервером для системы управления микроклиматом теплицы, имеющий два конечные состояния.

Ключевые слова: *микроклимат, теплица, управления, автоматическая система управления, микропроцессор, аппаратное обеспечение, элементная база.*

Introduction

The agricultural sector of Ukraine is of great importance for the economy and is the basis of its citizens' well-being.

The agro-industrial sector of Ukraine formed about 13% gross domestic product (GDP) in 2018. The share of agricultural products in total Ukrainian export during this period amounted to 39.8%, or a record $ 18.8 billion. The agricultural sector, due to its development, as well as, the decline of other industries, has established its status as a budget donor and among with information technologies (IT) is one of the leading sectors of the Ukrainian economy.

Since the greenhouses are an important part of the agricultural sector, the model of its management systems, its microclimatic indicators, as well as, its design and operational factors are highly relevant.

A greenhouse is an enterprise for the indoor growing of vegetables or seedlings for the open ground. The main structure of each greenhouse is a special cultivation room with a coating of translucent material (glass, polyethylene membrane). Heating in greenhouses can be provided by solar, biological (by biofuel), technical (hot water, steam, electricity, thermal waste of industrial enterprises, etc.) or geothermal energy sources. The main greenhouse crops are the vegetables (cucumbers, tomatoes, peppers, lettuce, horseradish, parsley, radishes, onions, celery, cabbage), melons (zucchini, melons, watermelons), fruits (lemon, peach), berries (strawberries), decorative flowers (carnation, chrysanthemum, rose, etc.) and mushrooms.

Greenhouses are very cost-effective: the cost of their construction pays off in 4-5 years.

Automatic control system for process plan of a greenhouse

Automatic control system for process plan (ACS PP) of a greenhouse is the basis of high yields and profitability of greenhouse production. It is known that the growth and development of plants directly depend on environmental conditions: the amount of light, heat, air quality, water, nutrients and other factors. Automated control of technological parameters allows us to control the microclimate in the greenhouse: temperature and humidity, carbon dioxide concentration, soil moisture and pH level, lighting, as well as remotely control the modes of greenhouse operation. The system of the automated microclimate control can include automatic watering, system of carbon dioxide replenishment, heating, ventilation, etc. Today, the ACS PP greenhouses are widely used by private farms to maintain the necessary temperature and humidity conditions in greenhouses.

The ACS PP of the greenhouses includes:

- automatic regulators, thermostats to maintain the optimum temperature;
- monitoring sensors to monitor temperature, CO2 levels, humidity;
- methods of automatic control for measurement of the controlled parameters;
- annunciators to inform about the reaching the set limit values;
- power supplies, switching and protective equipment, manual controls;
- engineering systems: ground heating; electric illumination; irrigation system;
- complete automation cabinet, ventilation equipment, auxiliary components, etc.

Automation of the process of growing greenhouse products provides full conditions for the development and plant growth. The usage of hardware and software complex of automated control of technological parameters of greenhouses means increasing profits and lowering production costs. The advantages of ACS PP of the greenhouses appreciated by agronomists, technologists, farmers and gardeners, as automated process control allows increasing output of greenhouse products and profits. With the help of an intelligent automated system, it is possible to monitor the parameters in the greenhouse around the clock, and adjust them remotely if necessary.

Functional capabilities of ACS PP of the greenhouses

"Smart greenhouse" is the key to successful crop production and economic efficiency of growing the greenhouse plants. ACS PP greenhouse operates as follows. The sensors record the values of technological parameters and transmit signals to the controller. Depending on the controller program the received data are processed and transferred to the personal computer or the smartphone in the form understandable by the operator (tables, mnemonics, graphics, etc.). Control signals can be issued from the controller to the activators to maintain the set values of technological parameters. By using the automated workplace the operator can set the necessary technological mode of operation of the greenhouse and control all ongoing processes.

Functionalities of ACS PP of the greenhouse:

- to control temperature automatically;
- to maintain the set parameters of a microclimate accurately;
- to display the technological information;
- to control and diagnostics of electrical equipment;
- to regulate process parameters.

ACS PP is a highly efficient tool for greenhouses, the purpose of which is to maintain optimal parameters for plant growth. Automation opens up new opportunities for greenhouse production and allows agribusiness to reach a new level. Thus, with the help of the automated climate control system of the greenhouse it is possible to maintain the required temperature and humidity regime, diagnose the technical condition of the equipment, use water, heat, energy resources economically. The introduction of ACS PP of the greenhouses helps to improve the quality of greenhouse products and increase the efficiency of crop production by maintaining acceptable climatic conditions, minimizing losses and reducing plant illness.

Formulation of the problem

The yield of greenhouses is largely determined by the microclimate, which is provided by modern computer control systems.

To evaluate the energy efficiency of greenhouses the indicator "energy consumption" is used, which characterizes the level of consumption of energy resources per unit of a product. The main problems of low energy efficiency of greenhouses are: excessive consumption of energy resources due to low energy efficiency of technologies and equipment and imperfection of schemes due to increased share of natural gas consumption and insufficient use of energy from alternative fuels and renewable sources; low level of management of energy efficiency and energy consumption.

Energy efficiency of greenhouses can be increased by such measures as the reduction of technological and non-production losses of energy resources by modernization of energy supply schemes and equipment, introduction of modern energy-efficient technologies, the optimization of the structure of consumption of fuel and energy resources, in particular, the replacement of traditional types of energy resources with other types such as renewable energy sources and alternative fuels, improvement of the management system of energy efficiency and energy consumption.

The main problem of developing intelligent components of microclimate control systems in greenhouses is the formation of requirements, the choice of data processing methods and the means of their implementation (software, hardware or software and hardware). Therefore, the actual problem is to design intelligent components and synthesize the adaptive computer systems for microclimate control and energy efficiency of greenhouses which adopt those components.

Software

Modern human society is surrounded by a large number of auxiliary mechanisms that facilitate the life of the individual. Every year, technology is getting "smarter", taking over many routine tasks that people previously had to deal with.

The most basic things such as greenhouse management, traffic light regulation, supervising indoor ventilation or heating systems, controlling elevators, and millions of other daily routines previously required the direct involvement of a human operator. Now the technological devices are controlled by computers and microcontrollers such as the Arduino Mega 2560 board, the heart of which is the ATMega2560 microcontroller.

The microcontroller is represented by a RISC processor developed by AVR and operates at a frequency of 16 MHz, which is the greatest in the entire ATMel product line. Its chip contains all devices related to the general concept of a computer system: reprogramming static, as well as flash memory, interface bridges, multiplier.

The processor is characterized as a calculator of a single response time to execute any command, regardless of its complexity. The address bus and internal registers is 8 bits size. The maximum size of the external SRAM memory which can be connected is 64 KB. The frequency setting generator is part of the controller chip itself.

ATMega2560, in addition to standard, discrete parallel and serial inputs/outputs, is equipped with analog signal converters.

Also in addition to the ATMega2560 microcontroller, the Arduino Mega 2560 board includes the following components:

- USB connector;
- reset button;
- ICSP1 connector;
- LED indication;
- ICSP1 connector;
- voltage regulator - 3.3V;
- ATmega16U2 microcontroller;

• external power connector;

• voltage regulator - 5V.

The main points of the model

The design of modern greenhouse climate control systems is based on system integration, which consists of a system approach covering all levels of integration of greenhouse management processes, and taking into account the requirements and efficiency of their application. It is expedient to develop greenhouse microclimate management systems on the basis of an integrated approach, which includes communication and information management technologies and systems, modern element base, software, decision support tools and is based on the following principles: consistency, equipment variability, openness, modularity, and usage of a set of basic design solutions.

The development of the modern control systems lies in the direction of reducing the size, weight and energy consumption, increasing reliability, functionality and intellectualization. Therefore, the new management systems based on new intelligent information technologies and a modern elemental base appear.

The microclimate in the greenhouse is controlled by a control system, the main components of which are: a microcontroller system, a mobile or PC operating system, sensors and activators (Fig. 1).

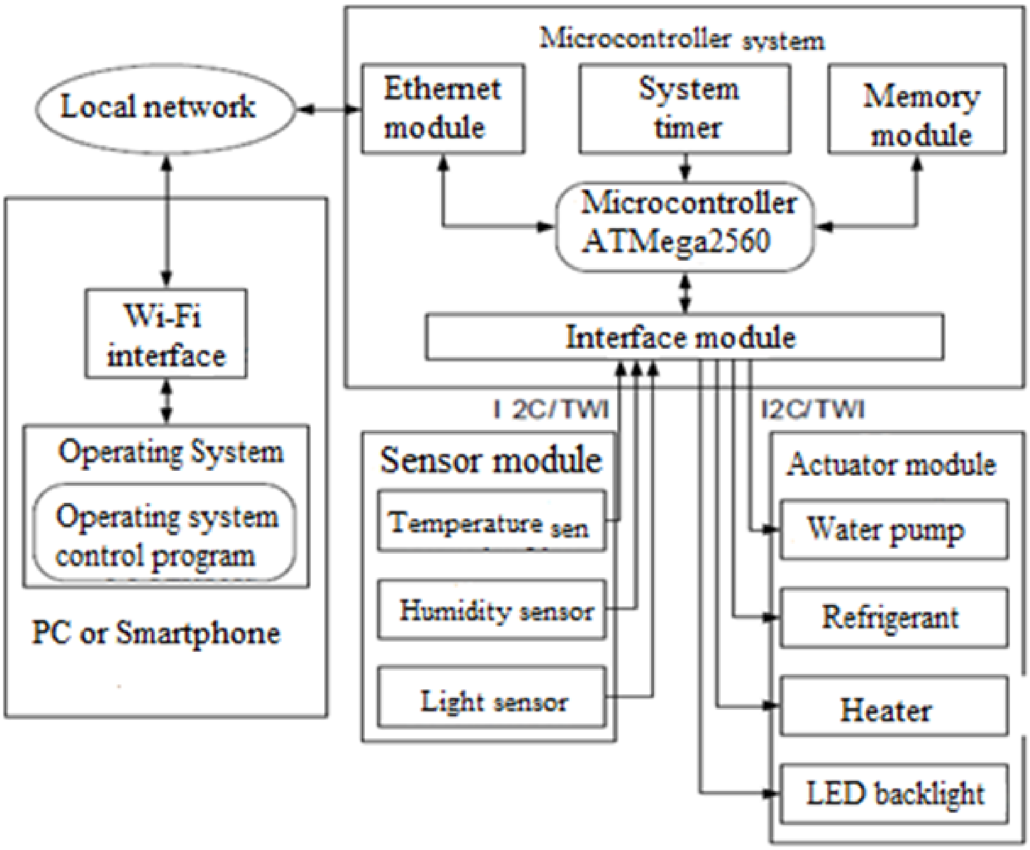

Figure 1. Block diagram of microclimate control in greenhouse

The microcontroller system consists of an Arduino board based on an ATmega2560 microcontroller, an Ethernet module, a memory module and an interface module.

The microcontroller connects all system modules into a single system. It is responsible for the autonomous management of the greenhouse microclimate. For this purpose, the microcontroller receives the sensor readings through the interface module and controls the activators according to the internal program.

The internal program analyzes the limits of the required parameters of the microclimate and generates control signals. If there is a connection to a mobile or computer control device, the microcontroller checks for changes in the greenhouse control parameters and overwrites the configuration file.

By developing intelligent components and using them in the control system, it is possible to effectively manage the microclimate and energy efficiency of the greenhouse. The study of the operations proves increased efficiency of this model. After the analysis of the element base and other indicators, it has been found that the proposed Arduino board based on the ATmega2560 microcontroller is efficient and on a par with the competitors.

The accessibility graph for the client-server communication in the greenhouse microclimate control system has been constructed (Fig. 2)

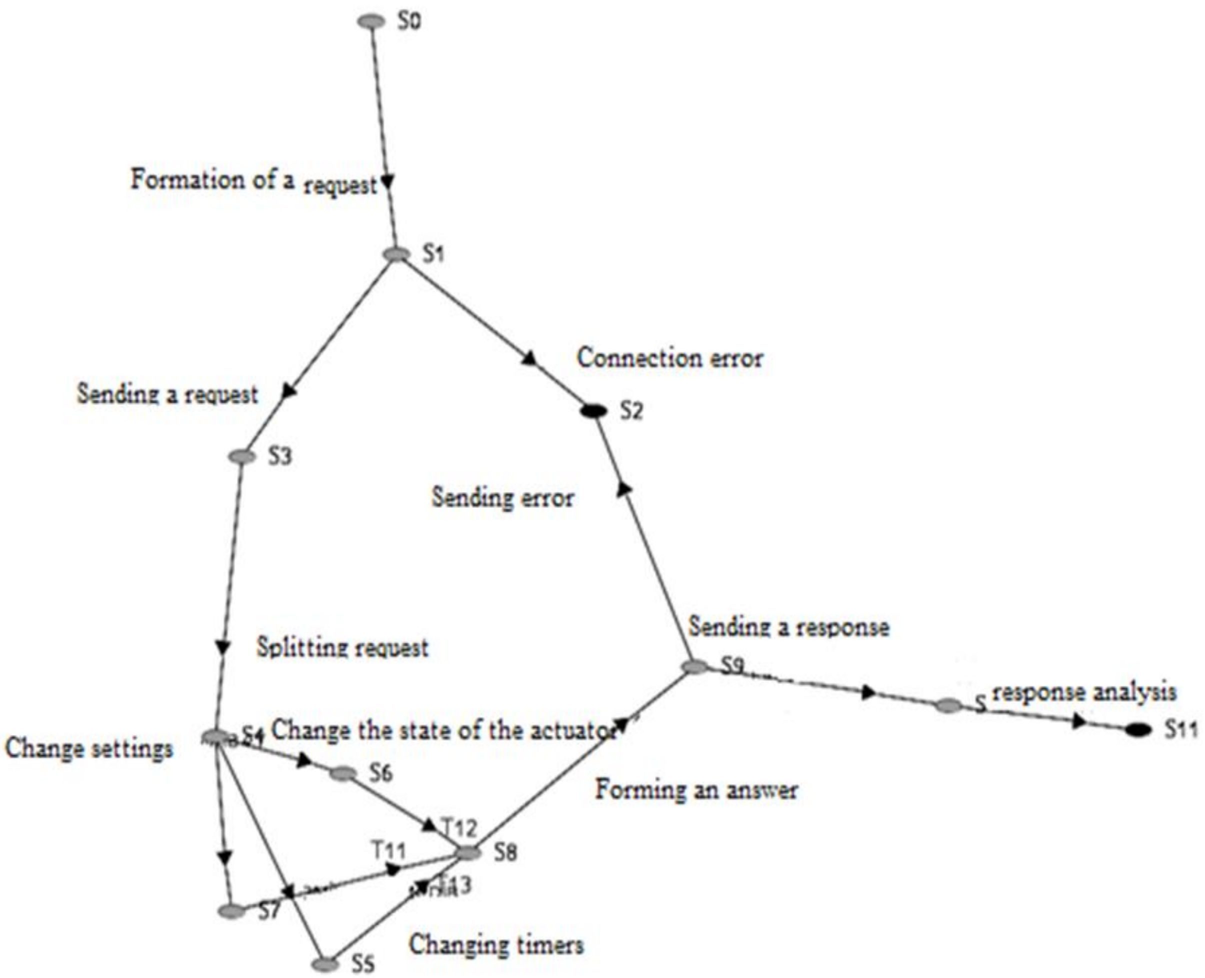

Figure 2. Accessibility graph for the client-server communication in the greenhouse microclimate control system

The accessibility graph for the client-server communication in the microclimate control system of a mini-greenhouse has two final states. The transition to the first final state means the successful communication between the client and server. The transition to the second final state means that a communication error has occurred and the requests have not been fulfilled. The accessibility graph is finite without blind spots and all states are reachable, therefore, the model works correctly.

Conclusion

Important trends in modern agricultural production are the constant growth of its scale, increasing the quantity and quality of agricultural products, on the one hand, and the progressive shortage of labor, the unpopularity of monotonous and heavy manual labor in agriculture and animal husbandry on the other. The complex mechanization and automation of production are of the utmost importance and sometimes the single way of resolving those contradictions.

Thanks to mechanization and automation of production, labor productivity could be increased greatly. The implementation of integrated automation is of great economic importance, because it guarantees a positive economic effect.

Automation of agricultural production increases the reliability and prolongs the equipment life cycle, facilitates and improves working conditions, increases occupational safety and makes agricultural work more prestigious, reduces labor turnover and saves labor costs, increases the number and quality of products, accelerates the process of erasing boundaries between mental and physical, as well as, industrial and agricultural labor.

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Надійшла – 12.08.2020