Ministry of Education and Science of Ukraine

ODESA NATIONAL UNIVERSITY OF TECHNOLOGY

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2023

PROCEEDINGS

ODESA, ONUT 2023

UDC 001.8(063)

Black Sea Science 2023: Proceedings of the International Competition of Student Scientific Works / Odesa National University of Technology; B. Iegorov, L. Ivanchenkova, M. Mardar (editors-in-chief.) [*et al.*]. – Odesa: ONUT, 2023. – 1109 p.

Proceedings of International Competition of Student Scientific Works «Black Sea Science 2023» contain the works of winners of the competition. The authors of the works are responsible for the accuracy of the information.

Odesa National University of Technology, 2023.

INTELLIGENT CONTROL SYSTEM OF GREENHOUSE MICROCLIMATE PARAMETERS

Author: Andrew Ostapenko
Advisor: Svitlana Kyslytsia
National University «Yuriy Kondratyuk Poltava Polytechnic» (Ukraine)

Abstract. *An important role in the formation of vegetable harvest in the greenhouse is played by its microclimate. However, existing systems of its provision in greenhouse structures have major disadvantages: temperature is not taken into account on the surface of plants; temperature differences from unreliable factors such as solar radiation, outside temperature and other outside changes, are not evaluated comprehensively. Therefore, conducting research aimed at developing methods, techniques and information-software tools for automating the control of microclimate parameters in the greenhouse is an urgent task. Based on the results of research, there have been conducted structural and fundamental schemes, algorithmic, informational guarantee of work for automated systems that manage parameters of microclimate in greenhouses.*

Keywords: *automated control system, greenhouse microclimate, neural networks, adaptive control system.*

I. INTRODUCTION

Meeting the needs of the Ukrainian population in vegetables during autumn, winter and spring requires the use of closed soil agricultural technologies. Since these technologies require significant energy costs (the agro-industrial complex of Ukraine consumes about 20 percent of energy resources, the cost of which is steadily increasing), a significant increase in the energy efficiency of technological processes in the cultivation of vegetables for domestic farmers is urgent.

The microclimate of the room and lighting of the plants play a decisive role in the formation of a crop of vegetables of excellent quality in the greenhouse. During dynamic modes of operation of the greenhouse, the values of temperature, humidity, illumination and the level of carbon dioxide in it significantly deviate from the optimal values.

The transfer of greenhouse farms to an industrial basis with the use of modern automatic systems for controlling microclimate parameters is the key to sustainable supply of vegetables to the population in the climatic conditions of Ukraine in the required quantity and high quality.

Existing systems for ensuring optimal parameters of the microclimate in greenhouses have a number of shortcomings - the temperature on the surface of plants is not taken into account, the influence of solar radiation is not comprehensively evaluated, the change in temperature and speed of movement of external air flows, the material and construction of the fence, as well as other factors that have random nature.

II. LITERATURE ANALYSIS

Significant value in the cultivation of vegetables in greenhouses have processes of automatic control and support of parameters of the microclimate, which determine the growth and development of plants in certain cultures. Not enough studies have been done in terms of research and development of automated parameter control systems of microclimates capable to work in greenhouses. Definition of basic adjustable parameters of microclimate in greenhouses, which affect growth and development of vegetables; comparative analysis of modern automated control systems in the greenhouse from the point of view of their energy efficiency and upkeeping of agrotechnical requirements is an important question.

2.1. Development of technologies for growing vegetables in enclosed soil

The vegetable market of Ukraine in the winter and spring periods of the year is provided as per account of enclosed soil structures, and at the expense of import vegetables.

To meet the needs of the Ukrainian population in vegetables it's in best of interests to expand domestic greenhouses. Lots of work is dedicated to the question of constructive and thermophysical characteristics of greenhouses.

To increase efficiency of vegetable growth in enclosed soil there are actively implemented promising energy and resource-saving technologies for growing vegetables with automatic support systems of microclimate modes. With this productivity reaches 35...40 kg of vegetables within 1 m^2, and with the usage of microclimate control system technologies and methods of plant growth stimulation, the harvest amounts significantly rise.

It is established that lack of automated management systems for maintenance of optimal climatic conditions in enclosed construction leads to overspending on energy carriers, reduction of harvest from different vegetable crops. Highest costs of energy carriers for heating greenhouses has been observed in December - February, when the air temperature descends below -10 °C. Solutions for establishing optimal microclimatic conditions at minimum energy consumption through software, despite a constant growth in energy prices, is an urgent scientific and technical task, the solution of which leads to an increase in profitability of vegetable products production.

These questions are solved through improvement of greenhouse structures, increasing the efficiency of heat sources for heating the coolant, as well as improving methods and principles for development of control systems microclimate.

A choice of control method for microclimate in greenhouses is determined, first of all, by the nature of disturbances to object management, its reaction to such influences and the opportunity for observation of them.

Parameters which determine the reaction of greenhouses on the specified influences on one side, and the microclimate in the greenhouse on the other, include temperature and air humidity, illumination, speed of air movement, dioxide carbon amounts, air temperature near plants, etc. [1-3].

Sources of disturbances are meteorological conditions on the territory of greenhouses, solar activity, work stability of the heat supply point. Given the random nature of meteorological conditions and solar activities on the territory of greenhouses, as well as oscillations of heat loss during heating, it is possible to assert the existence of currently undefined external influences. As a result, this causes currently undefined change of microclimate in greenhouses. At the same time, the characteristics of the environment change, causing change in thermophysical properties of materials from which the greenhouse is made. The appearance such changes alters communication between influences and reactions of the greenhouse. The need occurs for allocation of minimum parameter sets for the greenhouse microclimate, the knowledge of which will ensure the ability to effectively control said microclimate.

2.2. Methods and systems of greenhouse microclimate formation

Microclimate in greenhouse structures depends on a whole complex of parameters - temperature and humidity of air in indoors buildings; external temperature and speed of air; contents of carbon dioxide in the area where plants are located.

Lighting over plants and microclimate parameters play a decisive role in creation of optimal growing conditions for vegetables, as well as stimulating the main processes of their life activities: photosynthesis, respiration, transpiration, root and outside life supply.

It is established that contents of carbon dioxide in the greenhouse succumbs to significant fluctuations. At high CO_2 concentration in the soil the majority of plant root systems suffer.

Decrease of oxygen adversely affects plants. In soil, especially with complex air exchange that takes place in greenhouses, insufficient oxygen amounts cause death of roots or at least deceleration of breath.

An important indicator of transpirational ability in plants - relative air humidity. In order for transpiration to not stop, humidity in the greenhouse is kept at about 70%.

Ventilation systems [1, 2] include mechanical system for opening and closing two or three upper and side transoms simultaneously. In greenhouses two types of programming devices are used that manage the ventilation system. One can be used to regulate the degree of opening or closing the transoms, and with the help of the other open them as much as possible when exceeding the given temperature and close completely at a decreased temperature. There are systems in which transoms are opened depending on temperature and relative humidity in the air from an impulse from a special hygrostat.

To provide optimal soil moisture, the drip irrigation system is used in greenhouses [8]. Feed supply is adjusted automatically in certain time intervals under each plant in its root system. Signals for turning the drive on / off are received from systems controlled by sensor signals monitoring temperature and humidity. To provide optimal air humidity in the majority of greenhouses a sprinkler system is used, which is controlled by remote control management.

Thermal modes of greenhouses are supported by heating and ventilation systems. It is defined by the power of heat sources, as well as constructive features of buildings. Precision in maintenance of given temperature — within ±1°C. In addition, the set temperature must align with the level of illumination that is related to physiological specialties of plants' life activities [6].

Controlled and regulated influence on soil temperature, internal air temperature of the greenhouse, temperature of plant covering and the temperature of the fence during vegetable cultivation is changed through the power of soil and air heaters.

Maintaining necessary humidity in air and soil is done through the help of various irrigation systems (above-ground, underground, drip irrigation) [8].

The most important condition for receiving tall crops from greenhouse cultures is taking into account the relationships between modes and parameters, their coordination and support of necessary levels in greenhouses. Parameters exiting beyond the limits set by agrotechnical requirements during cultivation of vegetables in closed soil affects yield and marketable quality of products.

As indicated in works [9-12], greenhouse heating is carried out at the expense of solar radiation, biofuel, hot water or steam from boiler engines, industrial waste heat, electric heating installations. When heating the soil and air with hot water, quantitative temperature control is carried out. Research of transitional processes in greenhouses and structures of enclosed ground as an object of illumination regulation in the literature is not enough.

Electric heating of greenhouses significantly simplifies automatic control process of temperature and humidity of microclimate within greenhouses. Quality soil and air temperature control is carried out through heating elements, with the help of thermoregulating equipment - thermoregulators, thanks to which the heating system receives high degree dynamism and the ability to accurately maintain the temperature within the specified limits [11].

Heating soil in greenhouses is carried out with the help of (electrical shades, cables, mats, etc.). To provide optimal temperature for soil the capacity of 75-100 W/m^2 is enough [10].

It is fundamentally necessary to also use energy to provide sanitary and hygienic working conditions for workers, that includes energy costs for heating, lighting and ventilation etc. Side consumption of energy also includes energy to keep production capacities in working conditions.

The primary disadvantage of electric heating remains the cost of electricity. Price for every kWh of energy, as well as the economy of it, significantly affects the final cost, which means competitiveness grows in greenhouses products. Special value is given to management capacities heaters.

Change of heat supply from heating systems is carried out with regulation of temperature in the greenhouses. The greenhouse is the only energetically closed system, which consists of: heating subsystems, ventilation and heatsystems for enclosing structures.

For calculations of heating systems and ventilation in greenhouses it is important to fold adequate heat balance of the greenhouse, i.e to develop a mathematical model of technological process formation of an optimal microclimate in a real greenhouse.

Depending on the purpose and necessity of calculations in each specific case there are included the heat balance of all or few parts. In work [7] are given calculations for thermal losses in the greenhouse, which depend mainly on differences between external and internal temperatures and from methods and rules of temperature and humidity control modes.

Considered in the works are quality power management over the whole heating system, as in the management is related to change of heat carrier temperature.

During development of mathematical models of the greenhouse as an object of management, dynamic greenhouse air temperature dependence systems from the heat intensity of the heating systems are installed. The greenhouse is represented as an object of control with two volumes: air volume and soil volume. Considering the increase of temperature relative to height in the greenhouse, air temperature in the ground layers should be taken from 0.9 value at a height of 0.5 meters [19].

Heating systems in greenhouses are closely related to problems with energy saving, which are given many attention due to the fact that greenhouse vegetable growing is energy intensive in rural areas of economy.

Methods of microclimate management in the majority of industrial greenhouses are not optimal and do not take into account cross connections between parameters that lead to untimely coolant submissions, overspending energy and, as a result, lack of supply harvest vegetables.

2.3. Managemen technologies of microclimate parameters in industrial greenhouses

To choose optimal growing conditions of vegetables the microclimate mode is monitored for days according to plant growth phases, taking into account the differences of cultivated crops and varieties. As an example, in fig. 1 is presented the graph of changes in temperature and air humidity in the greenhouse over a day. At night, the temperature *t1* is maintained unchanged, an hour before sunrise, the temperature in the greenhouse increases to the value *t2*, air dries out, and at sunrise, water does not condense on plants and fruits, as such begins the normal process of photosynthesis.

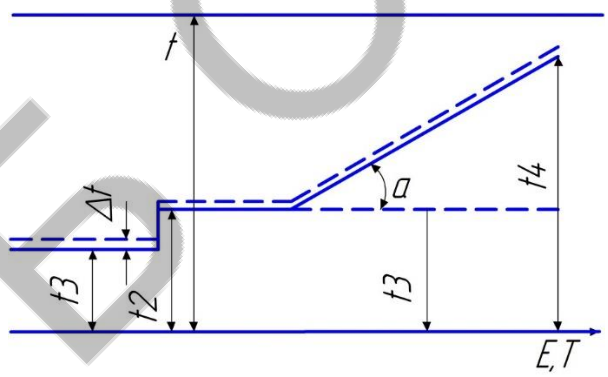

Figure 1 - Graph of dependencies between air temperature *t* in the greenhouse over a day taking into account illumination *and* the time of day *T*

During cloudy weather of day, the temperature *t3 is* maintained, equal to temperature *t2*. In sunny weather, starting with lighting of 2000 l k, the temperature is increased according to the value of illumination to temperature *t4*. After this ventilation transoms open, and excess heat leaves the greenhouse. Transition from daytime temperature until night is carried out after sunset. Angle of inclination *α* of line excess daytime temperatures in sunny days depends on the temperature on a cloudy day depending on the time of year.

Interconnection of microclimate parameters in the greenhouse and their changes over time, which are the basis of developed principles and program management of climate in greenhouses [19]. Changing the heat supply from systems heating and ventilation is carried out through control and regulation of temperature in the greenhouse rooms.

Based on the results of theoretical studies [2 3] greenhouse as a control object of the temperature and humidity modes, can be considered a multidimensional object of control and be presented in the form of a scheme (Fig. 2).

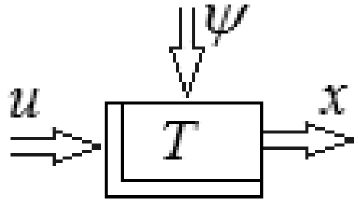

Figure 2 – Theorethical image of a greenhouse as an object managing its microclimate parameters

An extremely important criteria for management is economy of energy resources. It is known [7] that to achieve this goal there exist multiple options. The first is actively using lower contours of heating, because they give off the least heat to the outside environment. The second - upkeeping temperature near the growth point higher than near the roots of plants that allow active usage of upper heating contours. Another criteria of management is based on the fact that the lower contour should support the root zone's constant temperature, the so-called optimum, and only when other resources are exhausted executive systems should it deviate from it. Experience in implementation of automated control systems shows that at the stage of designing systems it is quite difficult to choose only one criteria of management. Therefore, the ability to quickly set criteria during operation should exist in the system, moreover the method of its task should display agronomic, economic and technical requirements that are required from the systems.

A modern management system should allow to set not only one of the above listed criteria or their combination, but also any another that occurs in the process of production, providing the agronomist-technologist with wide possibilities in choosing a method of maintaining the temperature and humidity mode in the greenhouse.

Microclimate management system in industrial greenhouses can manage:

– by three divided heating circuits - tent, above-ground, lateral;
– by two levels of heaters;
– by four drives of apartments.

Comparative analysis of existing microclimate parameter control systems in industrial greenhouses of the world's manufacturers allows to make a conclusion about the importance of optimization in systems of management. Which provides complex usage advantages of all the specified systems. The main parameters of greenhouse microclimate, which should be regulated, is temperature and humidity.

There are a few known levels of automation, with different completeness of performed actions and their complexity [7]. Systems of microclimate management in vegetable growing enclosed soil are described in many works [10-19]. Multifaceted analysis of this question is given in the works. Microclimate management system has a two-level structure. Upper level (operator post) is represented by a personal computer, and the lower one – by subsystems of management in greenhouses. Each of the subsystems has a local remote with a sign-digital indicator that provides control of the measured parameters and setting regulation contours. Lower level operates autonomously, carrying out microclimate management and forming daily measurement archives.

Microclimate management systems use a microprocessor controller. The controller registers value parameters of internal and external environment in greenhouses, after which management of executive devices occurs - heating, ventilation, shading, feeding carbon dioxide, evaporative moisturizing and cooling air.

Functions of upper equal management systems are performed by the central station, which provides centralized observing of all greenhouse structure modes and automatically archives parameters and freelance situations, as well as allowing centralized introduction of microclimate support settings for controllers of lower levels. Functions of management optimization are aimed for receipt of the most effective technological modes [13].

Today, one of the most important parameters in microclimate is humidity, which is measured constantly. Indicated requirements in combination with requirements for energy-saving technologies require the installation of big quantity executive systems in a greenhouse. It's divided into several contours of the heating system, blinds, fans and so on.

Heat supply system relative to temperature schedules, when the temperature of the coolant is hard tied to the external temperature, leads to some places of Ukraine to overspend of fuel or lack heat in the greenhouse.

Thus, the automated microclimate control system has to collect information and make decisions. Based on all collected data, a modern management system must calculate the necessary number of energy and distribute it between all heat sources. When using computer technology it is possible to improve the process of microclimate software in greenhouses using a modern neural network. Management system of temperature and humidity modes of the greenhouse from a computer application consists of hardware and software provision. It gets information from many sensors:

- external - speed and direction of wind, air temperature, lighting, humidity, precipitation intensity, position of transoms and the screen;
- located within greenhouses - temperatures and humidity in different departments, CO_2 concentration, temperature of plants, sensors that measure the intensity of natural and artificial light radiation in the most spectral region important for photosynthesis between 400 and 700 n.m.

System with supported software is performed through a personal computer together with the controller for communication with sensors, allowing to adjust the temperature in the room of the greenhouse and its microclimate as a whole, decides the following tasks: 1) displays on memory cards and records in the computer for a long time (several months, years) the temperature and humidity of air in the greenhouse and outside, wind speed, temperature and pressure of forwards and backwards water streams in the heating circuits, atmospheric pressure, lighting, etc.; 2) supports required temperature and air humidity within the necessary limits of the greenhouse structures; 3) uses steam heating or others systems heating for regulation of temperature; 4) controls transom drives; 5) informs the operator when the controlled parameters exit acceptable boundaries; 6) records emergency situations in files.

Features of such systems are, on the one hand, simplicity and, accordingly, low costs, and on the other hand, insufficient cost quality management, impossibility of operational accounting of all controlled parameters and exact matching of many technological systems, high degree responsibility on service personnel and dependence from their qualifications and experience.

Increase in efficiency related to the necessity of intellectualization of the choice process of the dispatcher's decision in complex systems. The first step on the way to increasing effectiveness of local automatic control systems with separate technological parameters (temperature of the coolant in the heating circuits and water in the irrigation system, pressure drop in the heating network, liquid levels in containers, solution concentration etc.) on the set levels [14, 15]. Usually separate parameters are located under influence of small quantity disturbances and interferences and therefore are relatively easy and reliably are carried out by their automation management. In general, the whole set of individual technological parameters forms microclimate in the greenhouse, determining the conditions for growing a harvest. As a rule, individual self-propelled guns for different technological processes are installed and function regardless of each other, representing autonomous systems. Creation of such self-propelled guns allows to raise the quality of management for separate technological parameters, releasing simultaneous dispatchers from enough time-consuming and monotonous work that indirectly helps increase the quality of support for the microclimate in as a whole.

On the other hand, low quality coordination between effects on individual parameters of a microclimate marginally limits possible increase in efficiency. The next step on the way to increasing efficiency became the creation of automated microclimate control systems (ACS) in greenhouses, which provides support parameters for microclimates (air temperature, soil, humidity of air and soil, lighting level, parameter systems for nutrition of plants) on the set levels [2 3]. Such systems affect the entire complex of technological processes in the greenhouse, including systems that separate water heating, calorific and/ or gas heating, transom or recirculation ventilation, blinds, electric secondary lighting, volatile cooling and permitting air (mist system) etc. In such systems, the goal of control is not a separate executive mechanism, and parameters of a microclimate, the main of which are temperature and humidity of air.

From the conducted comparative analysis capabilities of microclimate control systems in industrial facility greenhouses of the world manufacturers and information laid out above, it can be seen that all considered systems are not taken into account the irregularity of energy carriers consumption that leads to them overspending.

In the simplest case energy efficiency from use of management systems is expressed through savings on energy costs under the condition of compliance with the regulatory requirements of the microclimate.

One of the promising directions for decrease of expenses on growing products, assuming compliance to agrotechnical requirements is electrical heating.

As can be seen from the analysis of the state of research in the field automation processes, microclimate management in the greenhouse to achieve the goal of research is possible during implementation of methodology systems of automatic control of the temperature and humidity modes. By choice such methodology affects many factors [16]: the nature of the change signals in control paths, disturbances; dynamics greenhouses as an object of management; type and properties regulatory bodies; source type energy, etc.

Considering complexity of direct measurement between value norms of effective energy consumption and communication of its importance and agrotechnical conditions growing certain crops in the greenhouse, it becomes clear that for the increase of energy efficiency in the process of growing vegetables at the expense of automation process management it is best to develop an analytical system of self-adjustment with a neural network calculator.

When practical implementation of such systems occurs the need for technical means capable of performing measurements of the indicator of the goal of management in the conditions of uncertainty.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The purpose of this section is development and research systems control of the temperature and humidity regime in the greenhouse on the basis of experimental data and created mathematical models that describe the temperature and humidity regime in the greenhouse. Expediency application of artificial neural networks for construction of intellectual systems of temperature and humidity regime management in the greenhouse confirmed non-linearity and complexity intrasystemic connections.

Existing systems for ensuring optimal parameters of the microclimate in greenhouses have a number of shortcomings - the temperature on the surface of plants is not taken into account, the influence of solar radiation is not comprehensively evaluated, the change in temperature and speed of movement of external air flows, the material and construction of the fence, as well as other factors that have a random nature.

In order to study the influence of these factors on the yield of vegetables in the greenhouse and the possibility of controlling the parameters of the microclimate and lighting of the plants, we developed and created a layout of the greenhouse, which is equipped with the latest electronic equipment, modern executive mechanisms and an intelligent system that provides automatic control of the microclimate of the greenhouse and the lighting of plants at compliance with the energy saving mode (Fig.3).

Control of soil and air temperature is carried out by fast-acting temperature transmitters placed, respectively, in the soil at the level of plant roots and in the air.

The executive mechanism for regulating the soil temperature in the greenhouse layout is resistive heating elements powered by the electrical network. Heaters, electric heating carpets, etc. can be heating elements. There is also an executive mechanism that quantitatively controls the flow of liquid coolant in a real greenhouse. Thermal mirrors are used to reduce heat losses directed in the direction opposite to the plants.

Figure 3 – External appearance of the greenhouse layout

Air heating in the greenhouse is carried out with the help of a ventilation system with a recuperative air-to-air heat exchange device, which simultaneously takes into account the level of carbon dioxide according to the given air exchange.

To heat and ensure the optimal composition of the air in the room of a real greenhouse, it is suggested to use a supply and exhaust system of the VUT type with heat recovery. The power of the installation is determined by the volume of the greenhouse. It is possible to control the air temperature in the greenhouse using infrared heaters.

Humidity control of the greenhouse atmosphere is carried out using a humidity sensor. Air humidification is optimized using a fog generator.

To equalize the heat and moisture fields in the volume of the greenhouse model, a fan, shown in Fig. 4, is designed.

Figure 4 – Fan equalizing heat and moisture fields

Measurement of natural external illumination is carried out by an illumination sensor. The sensor is placed on the external upper transparent surface of the enclosure of the greenhouse layout.

When the external illumination is reduced to a critical level, the automatic switching on of the LED lamp, made of a block of LEDs emitting in different parts of the visible radiation spectrum, is provided (Fig. 5).

Figure 5 – Appearance of LED lamps

The spectral composition of the lamp's radiation is adjusted to a certain type of plant. The individual need for the spectral composition of the radiation of a certain type of plant is satisfied by the appropriate setting of the lighting system.

The content of carbon dioxide is determined using a suitable sensor. The unified electric signals of the sensors, which inform about the state of the microclimate parameters of the greenhouse, are directed to the original information processing device, created on the basis of a microcontroller Arduino (Fig. 6). An information processing device connected to a personal computer forming an intelligent system for controlling the temperature and humidity regime of the microclimate of the greenhouse and lighting the plants in it.

Figure 6 – Appearance of the information processing unit

An original program has been developed for processing parameters of technological information and control of executive mechanisms.

Figure 7 – Appearance of the information processing device

The developed and implemented intelligent automatic control system allows local and remote monitoring, control and management of microclimate parameters and greenhouse lighting parameters using the GPRS system. The system can be adapted for both industrial and private greenhouses.

IV. RESULTS

An operational layout of the greenhouse was developed for the study of the developed original system of automatic local and remote control of microclimate parameters based on the domestic K-1 microcontroller with its subsequent adaptation to greenhouse farms.

The designed and manufactured operating model of the greenhouse has an automatic control system based on the K-1 multi-channel programmable controller, which makes it possible to quickly and automatically control the microclimate of the greenhouse, providing optimal conditions for growing vegetables.

In fig. 8 main elements of the greenhouse layout are schematically presented: 1 – the body of the layout, made of transparent polystyrene; 2 – a metal tray with soil for growing vegetables; 3 – resistive thermal elements of soil heating; 4 – reflective thermal mirrors; 5 – resistive air heater with a nozzle that has a fan; 6 and 7 – thermoresistive measuring transducers of the TOM-1 type for measuring soil and air temperature, respectively; 8 – measuring transducer of air humidity type DV-2. 9 – fog generator and 10 – fan are used to ensure uniform air humidity in the volume of the greenhouse.

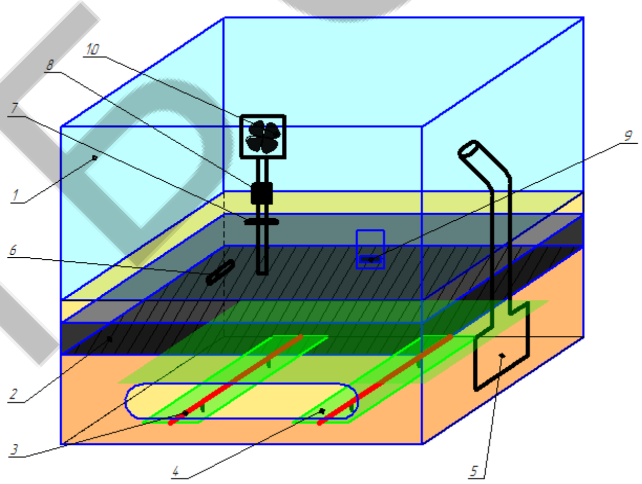

Figure - 8 - External appearance of the greenhouse layout

A personal computer connected via an interface to the system of automatic control of the microclimate parameters of the greenhouse layout allows for local and remote monitoring, control and management of the microclimate parameters of the greenhouse using the GPRS system.

Designed and manufactured a laboratory-demonstration working model of a greenhouse, which has an automatic control system based on a multi-channel programmable microcontroller K-1 combined with a personal computer gives the opportunity to familiarize with the principles of automatic local and remote measurement, control, management and monitoring of greenhouse microclimate parameters using the GPRS system. Re-equipment of greenhouse farms, transferring them to an industrial basis with the use of modern automatic systems for controlling microclimate parameters makes it possible to solve the problem of sustainable supply of the country with high-quality vegetables in the required quantity.

K1 is a multi-channel panel programmable logic controller designed to control technological processes in greenhouses.

Function is implemented as a programming language in the K1 controller Block Diagram (FBD). K1 contains a library of functional blocks, which is divided into several conditional groups: input-output blocks, mathematical, logical, process control 1, process control 2, miscellaneous.

The process of programming the controller is the construction of a scheme of the technological process with the help of virtual functional blocks located in its library.

Programming of the controller from a computer is carried out in the P-CAD environment using a library of functional blocks. The proposed system of automatic control and management of greenhouse microclimate parameters based on the K-1 controller is designed for:

- microclimate control in the middle greenhouses,
- external tracking weather conditions,
- analysis of received data

developed automated control system based on the K-1 controller can be implemented in any greenhouse.

V. CONCLUSIONS

When performing the research, the following results were obtained:

1. It has been proven that the reasons for the decrease in the efficiency of growing vegetables in enclosed soil are related to the shortcomings of the existing approaches to the creation of temperature-humidity control systems.
2. The analysis of models of the dynamics of the arch type greenhouse, obtained analytically and experimentally, showed its controllability and observation, if soil and air heating are used to control the microclimate. The expediency of air temperature changes with constant soil heating has been established.
3. It was established that the input data required for the operation of the sampling unit of the temperature-humidity control system in the greenhouse should include: external air humidity, heat index, internal air humidity, air temperature near the plants.
4. As a result of the synthesis of an intelligent adaptive automatic control system, the following software modules were developed: a control system, a database, a software block for forming a sample of technological data, which made it possible to create a convenient interface for the operation of operational technologies.

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