Control System of Electrotechnical Phytotron Complex with the Use of Internet of Things Technology

Taras Lendiel [a], Nikolay Kiktev [a, b] and Natalia Pasichnyk [a]

[a] National University of Life and Environmental Sciences of Ukraine, Heroiv Oborony str., 15, Kyiv, 03041, Ukraine
[b] Taras Shevchenko National Univercity of Kyiv, Volodymyrs'ka str., 64/13, Kyiv, 01601, Ukraine

Abstract

The analysis processes that take place in the phytotron, a mathematical model of the phytotron, were carried out for further development of the automated control system using the Internet of Things (IoT) technology. The functional-algorithmic scheme of the phytotron and the algorithm of remote temperature control of this object are developed. The software and hardware implementation of the control system for the phytotron is based on the integrated Arduino board. Reads information from sensors, also developed an operator interface in the form of a mobile application, in addition to recording the measured values in the database on the server for further processing. It is possible to store files in the cloud and remotely control processes from a mobile device. The software provides an address poll of the sensor, which allows you to estimate the change in the controlled parameter at the location of the sensor. The structural scheme of the electrical complex of the phytotron and the scheme of control of this technological object with the use of IoT technologies are given.

Keywords

Internet of things, cloud technologies, platform, software, algorithm, phytotorn, electrotechnical complex, interface, information control system.

1. Introduction

To study the development of plants, it is necessary to conduct constant phytomonitoring of the plant and their development environment. To determine the influence of disturbing factors on plant development, a system of phytomonitoring of technological parameters in the phytotron has been developed. The developed system uses the approach of Internet of Things technology for remote monitoring of the technological process and switching of connected devices of the electrical complex in the chambers of phytotron cultivation. An effective solution to the problem of growing (producing) agricultural products in modern conditions of agribusiness is achieved by introducing information and control systems at production sites. In this regard, the problem arises of creating a hardware-software complex based on modern automation tools. In recent years, new directions in automation systems and IT have been actively developing - cloud technologies and the Internet of Things (IoT), which have found successful application in agricultural production, given the length of control objects and their remoteness from decision-making centers. Today, IoT is the most modern tool for industrial automation, which allows remote monitoring of the state of an object (including biotechnical) and remote control of drive mechanisms and devices located at the object.

2. Literary review and purpose of research.

Many researchers from Ukraine and other countries were engaged in the study of the problems of the phytotron and greenhouses and the use of Internet-of-Things technology to control parameters. Scientists from Belgium and Morocco R. A. Abdelouhahid, O. Debauche, S. Mahmoudi create a personal phytotron at an affordable price thanks to a wide range of hardware, cloud computing and

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EMAIL: taraslendel@gmail.com (A. 1); nkiktev@ukr.net (A. 2);
ORCID: 0000-0002-6356-1230 (A. 1); 0000−0001−7682−280X (A. 2); 0000-0002-2120-1552 (A. 3)

new opportunities offered by the Internet of things (IoT) [1]. Taiwanese researchers Yu-Chun Chu and Jer-Chia Chang in the chambers of the phytotron tested the temperature regimes, relative humidity and illumination as environmental parameters for growing seedlings or plants in different phases of development [2]. Phytotrons with various electronic control systems are also being created to assess the effect of technological parameters on plants when breeding new varieties. One of them is described in a study by Algerian scientists H. Adjerid, Y. Remram and M. Attari [3]. The researchers presented an electronic control system that includes monitoring and control of air temperature, relative humidity and lighting as environmental parameters. This made it possible to form a new phytotron typology based on two growth phases in order to study the impact of climate change on plants.

In milk production, animal health monitoring is carried out, which includes data tracking using IoT tools. This allows you to know at what point in time you need to change the feed ingredients. There are also technologies for monitoring the quality and quantity of feed grains and oil crops [4]. According to the author, IoT technology is best suited for tracking the location and feeding of animals in a meadow or in a barn. Connecting a collar with sensors to cows allows continuous monitoring and optimal nutrition planning.

Latin America is implementing the latest precision farming technologies, and this technology will be included in AquaSim, a set of customizable IoT productivity tools [5]. The aquaculture division Nutreco Skretting together with the Eruvaka company is implementing IoT in fish farming [5]. IoT technologies in agriculture are intensively used in India, where, due to population growth, the problem of food saturation is acute. The project described in the work of researchers L. Abhishek and B. Rishi Barath [6] includes the automation of technological processes in agriculture, including the measurement of soil moisture, so that the farmer can decide whether to use wet or dry crops depending on the conditions. as well as water level measurement. In another project, described in the work of Indian researchers K.R. Raghunandan, L.J. Quadras et al. [7], IoT technology is used in the following technological processes:

- automation of irrigation - a system based on soil moisture and water level, measuring moisture, temperature and dew point;
- lighting control - automation to save energy;
- security alarm using infrared radiation;
- sending from a sensor located on farmland, a report to the farmer using a notification system.

One of the options for applying the technologies was proposed by professors of the Institute of Electrical and Electronics Engineers K.A. Patil and N.R. Keil [8]. A "Smart Agriculture Model Using the Internet of Things" has been developed, which implements a real-time soil monitoring system, monitors soil moisture content, acidity and temperature, and these values are used to deploy support and decision-making systems. This system helps in identifying crop pests and diseases and sends SMS alerts to the owner. The proposed architecture consists of three modules: client-side, server-side, and farm-side. The standard Ubi-Sense Mote (M) sensor board is used to measure temperature, humidity, barometric pressure and proximity. The data collected by Ubi-Sense Mote is then sent to the server. The server part consists of a support and decision making system that sends the required information received from the sensors to the client side, which consists of a web application and a mobile application for Android. The disadvantage of this system is that no methodology for improving irrigation facilities is proposed, and the mobile application is not available for iOS phones.

Another method, considered by P. Patil and A. Narhidi [9], involves the use of a soil moisture sensor, which measures the value of the moisture content in the soil at fixed intervals. When the soil moisture level is registered below the threshold value, an SMS notification is sent to the user. The main disadvantage of using this method is that data is sent at a fixed time interval. Minimizing the interval will result in excessive energy consumption, increasing the interval may damage the crop. This system will be useful for monitoring the state of soil moisture on the farm, as well as for controlling soil moisture by monitoring the water level in the water source and, accordingly, turning on / off the motor for irrigation purposes and using the PIC16F877A and GSM SIM300 modem. The system offers a soil moisture sensor in every location where moisture needs to be monitored. Another proposed system is the "Intelligent irrigation system for automating the maintenance of field conditions based on the Internet of Things", proposed by N. Rao and B. Sidhar in 2018 [10]. Two sensors, a soil moisture sensor and a temperature sensor, are placed in the crop field. Data from these sensors is collected using the Raspberry Pi microcontroller, a series of single-board minicomputers originally developed in the UK for teaching in schools, but with widespread use.

The sensor readings are sent to the Raspberry Pi controller, in which the Apache web server is configured. The Raspberry Pi also has a storage such as SQL database or container. The ZigBee module is used to establish a communication channel between the sensor arrays and the server. The farmer can access the field status server anytime, anywhere, thereby reducing labor and time.

Mmultishock communication has been implemented to increase the communication range. Data from sensor arrays are transmitted through neighboring sensor matrices for further transmission to their neighbors. The data is then sent to the database using WiFi, so the user of this system can track changes and draw up an irrigation plan at his own discretion. The disadvantage of this method is that no security protocols are implemented in the system.

IoT livestock management solutions make livestock monitoring more affordable than ever before. Livestock monitoring solutions are based on portable sensors mounted on the body of animals [11]. These sensors can track heart rate, blood pressure, temperature, breathing rate, and even digestion and send the data over the Internet to a central computer for further analysis. With the help of these sensors, farmers can also track the location of individual farm animals, identify sick ones, and track their optimal grazing regimes. This can help farmers respond quickly to an infected animal and stop disease transmission to other animals in the herd.

Researchers from Ukraine A. Zhiltsov, I. Bolbot et al. in the article [12] substantiated phytomonitoring in a greenhouse using non-contact visual assessment of plants. The basis of such an assessment is the performance of photography of plants by a special electrical complex, after which the stored images are recognized using wavelet analysis technology. The use of this photo technology as a means of non-contact information makes it possible to assess the growth and condition of plants in a greenhouse and predict their development using mathematical transformations, which will allow us to estimate future crops. The authors have developed a recognition algorithm, it is used to recognize biomass in the greenhouse space.

In the work of Ukrainian researchers V. Lysenko, T. Lendiel and D. Komarchuk [13], a hardware-software subsystem for phytomonitoring in a greenhouse was implemented based on the LabVIEW software environment and Arduino hardware support, and this subsystem was tested in industrial production - JSC "Combine Teplichny" in the Kyiv region. It is shown that when growing vegetables, along with the temperature characteristics of the environment, information about the temperature of plants is important. The dependence of the temperature of plants on the illumination in the greenhouse was analyzed, and an improved mathematical model of the greenhouse was obtained, suitable for the formation of control actions, taking into account the spatial location of the control object. In a work with the participation of the authors of this article [14], N. Kiktev, T. Lendiel and V. Osypenko proposed using the Internet of Things technology in agricultural production, in particular, in the production of feed. The work contains a combination of software and hardware solutions based on the Arduino control board with mathematical models for optimizing the composition of feed according to the criterion of maximum yield of a substance with nutritional restrictions on feed components.

Researchers from Qatar, Morocco and Canada A. Ouammi, Y. Achour et al. [15] presented a comprehensive energy management system based on the centralized control of an intelligent greenhouse. Such management allows optimizing and controlling the global indoor environment for growing crops. The development is to implement a comprehensive predictive control (MPC) energy management platform that takes into account the volatile behavior of renewable energy production, the dynamics of energy and water storage, as well as uncertainties associated with climate conditions. The authors propose a multi-purpose integrated optimization system for managing the operation of a smart greenhouse, taking into account forecasts and updated data collected from an available network of wireless sensors.

An interesting study by Turkish scientists M.A. Akkasha and R. Sokulu [16], who presented a prototype consisting of MicaZ blocks, which are used to measure temperature, light, pressure and humidity in greenhouses. The measurement data was provided via the Internet of Things. With this system, farmers can manage their greenhouse from their mobile phones or computers connected to the Internet. Canadian researchers M. Bozchalui and K.A Canizares in their article [17] presented a new hierarchical approach to management and new mathematical models for optimizing greenhouses, which are easily integrated into the energy center control system.

An article by Chinese researchers Yin Ding, Liang Wang et al. [18] proposes the use of intelligent algorithms in modern agricultural production, which requires database support, which can be complex and difficult to use in practice and requires a large amount of computation. A predictive model (MPC) is proposed that can provide high-precision control operations at moderate complexity, and also allows running optimization in a limited time interval, which improves accuracy. Other Chinese researchers J. Hou, and Y. Gao [19] propose the development of a solar-based greenhouse greenhouse sensor monitoring system. It transmits data using wireless equipment for receiving and sending without installing wiring. Compared to conventional wireless technology, this system design consumes less energy, costs less money and has a higher Internet bandwidth. Sensor nodes receive solar energy and supply it to a wireless sensor network. This system uses the MSP430 microcontroller with ultra-low power consumption and the nRF24L01 low-power network transmission chip to minimize system consumption. Moreover, this system uses multilevel energy memory. It combines energy management with energy transfer, which allows you to wisely use the energy collected by solar panels. Thus, a self-managing energy supply system was created.

Romanian researchers R.-O. Gregory, A. Water et al. [20] offer temperature control of a greenhouse heated by renewable energy sources. Based on the linearized model, a PID controller was set up, which was used to control the internal temperature in the greenhouse.

The software and hardware implementation of the information management system as applied to various biotechnical objects based on the Arduino integrated board and the LabView visual programming environment is considered by the authors of this article in [21]. In addition to reading information from sensors, an operator interface was also developed in the form of a web page, as well as recording measured values in a database for further processing. Data is stored on a storage device in the form of tables unified with data processing programs. It is possible to store files in the cloud and remotely control technological processes.

The purpose of the study is to develop and implement a system of phytomonitoring of technological parameters of cultivation in the phytotron and the ability to remotely switch the connected devices of the electrical complex.

3. Research materials

3.1. Mathematical model of the phytotron

The mathematical model of the phytotron is based on the heat balance equations for the greenhouse [22]. For a phytotron, it is assumed that its space is the temperature zone around the perimeter, taking into account the design features of its growing chamber. According to the parametric scheme of the equation of heat balance for each zone can be written as:

$$Q_i = Q_t + Q_k + Q_t + Q_v + Q_c, \quad (1)$$

where Q_i is the amount of heat in the phytotron chamber, J; Q_t is the amount of heat from the heating system, J; Q_k is heat loss transmitted through the side walls, J; Q_t is heat consumption transmitted through the end walls, J; Q_v is the amount of heat to heat the ventilation air, J; Q_c - heat from radiation lamps, J.

The amount of heat in the phytotron chamber depends on:

$$Q_i = C_p V_p \rho_p t_p , \quad (3)$$

where C_p is heat capacity of air, J / kg · ° C; ρ_p is air density, kg/m^3; t_p is air temperature, °C; V_p is the volume of the phytotron chamber, m^3.

The amount of heat given to the phytotron chamber by the heating system is determined by:

$$Q_t = k_{tp} S_t (t_{w,i} - t_i) , \quad (4)$$

where k_{tp} is heat transfer coefficient through the wall of the heating system pipe W/m·°C, S_t is heating surface area, m^2; $t_{w,i}$ is heater temperature, °C; t_i is air temperature in the phytotron, °C.

The model also takes into account the effect of heat from radiation lamps, J., which is equal to: ,

$$Q_c = k_s S_{k,i} O_{cv} \quad (5)$$

where k_s is the heat transfer coefficient due to additional lighting, W/m·°C; $S_{k,i}$ is area of the base of illumination, m^2; O_{cv} is intensity of illumination, W/m^2.

Heat consumption is determined taking into account all the end surfaces of the phytotron chamber, which borders the corresponding temperature zone:

$$Q_v = k_{pz}(S_{b,i} - S_{k,i})(t_i - t_z), \quad (7)$$

where k_{pz} is the heat transfer coefficient through the end surfaces of the phytotron chamber to the external environment W/m^2 · ° C; $S_{b,i}$ is the area of the end surface in the chamber, m^2; t_i, t_z is outdoor air temperature, respectively, °C.

The functional-algorithmic scheme of the phytotron complex will look like Fig. 1.

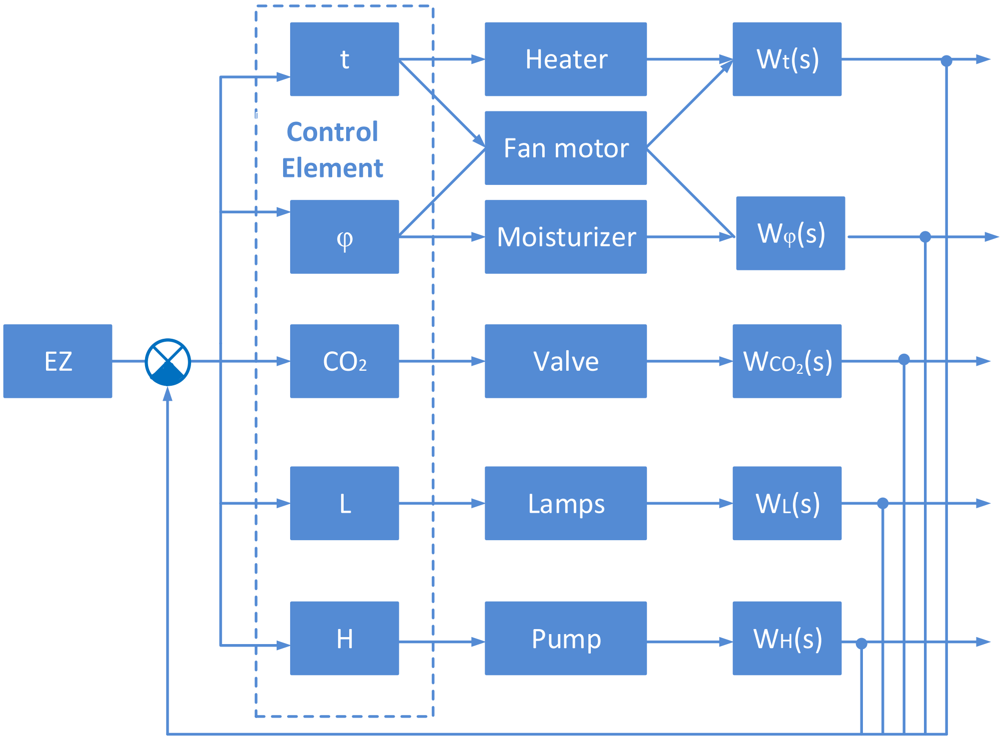

Figure 1: Functional-algorithmic scheme of the phytotron: EZ - reference element; W_t *(s)*, W_φ *(s)*, W_{CO_2} *(s)*, W_L *(s)*, W_H *(s)* - transfer functions of the control object in terms of temperature, humidity, air pollution, lighting and irrigation.

3.2. Algorithm for remote temperature measurement

To study the development of plants in the management of the technological mode of plant growth, I use phytochambers, in combination with all the equipment is a phytotron. The phytotron is a chamber with the created artificial climate where it is possible to regulate temperatures, humidity and gassiness of air, and also management of watering and lighting.

The control system operation algorithm is shown in Fig. 2. The system works as follows:

1) after the presentation of the power supply, the entire system is initialized, the critical value of the time t_k is entered;

2) the effective value of the time t is compared with the critical value of the time t_k (the time during which the entire technological process takes place);

3) measurement of technological parameters;

4) check the wireless connection, assign an ip-address;

5) when connected via wireless communication, the measured value is displayed;

6) waiting for the command; go to item 2;

8) if there is no wireless connection, the system goes into automatic mode;

9) after the transfer of the control action to the actuators, data is sent to the personal computer of the general control system; go to item 2.

11) when the critical time is reached, the program ends.

The general algorithm of the specified is shown in Fig. 2. One of the most important features of the ESP8266 is that it can not only connect to an existing Wi-Fi network and act as a web server, but can also set up its own network, allowing other devices to connect directly to it and access it. to web pages. This is possible because the ESP8266 can operate in three different modes: station mode, access point mode and both first modes simultaneously.

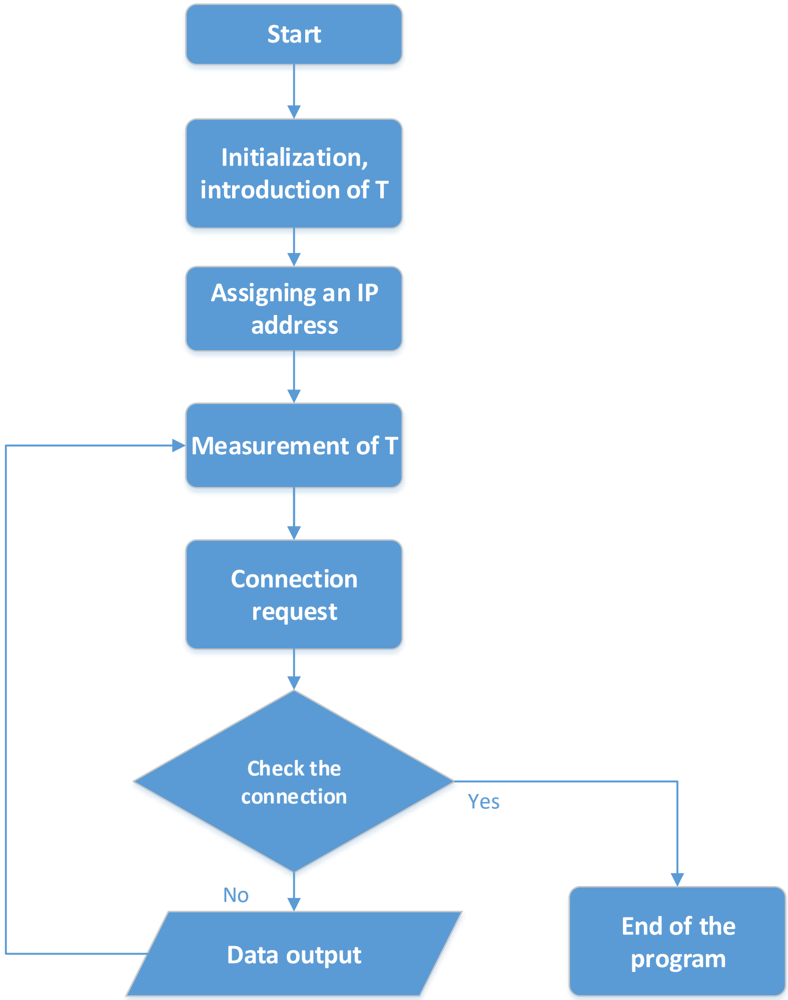

Figure 2: Algorithm for remote temperature (T) measurement

4. Research results.

During operation, the phytotron control system provides real-time data collection and processing in the phytotron, plays the role of a controlling component of the parameters of plant phytodevelopment and technological parameters of the microclimate. The set of hardware used in this case - hardware and software environment of Arduino. Their diversity and availability have created the conditions for the successful implementation of automation systems that operate on the basis of Internet of Things technologies. The technological scheme of phytotron operation is made (Fig. 3):

- *K1* and *K2* - 1st and 2nd phytochambers;
- *L1*, *L2* - lamps of the 1st and 2nd chambers;
- *C* - LED backlight;
- *B1* and *B2* - fans of the 1st and 2nd chambers;
- *H* - pump; *P* - heater; *G1* and *G2* - humidifier 1st and 2nd;
- *O1* and *O2* - light sensor (inclusions *L1*, *L2*);
- *T1* and *T2* - air temperature sensors (inclusion P);
- *T3* and *T4* - Plant temperature sensors (pyrometers);

- T5 and T6 - substrate temperature sensor (DS18b20, DHT11);
- *F* - humidity sensor (DHT 11) (inclusion *G1*, *G2*).

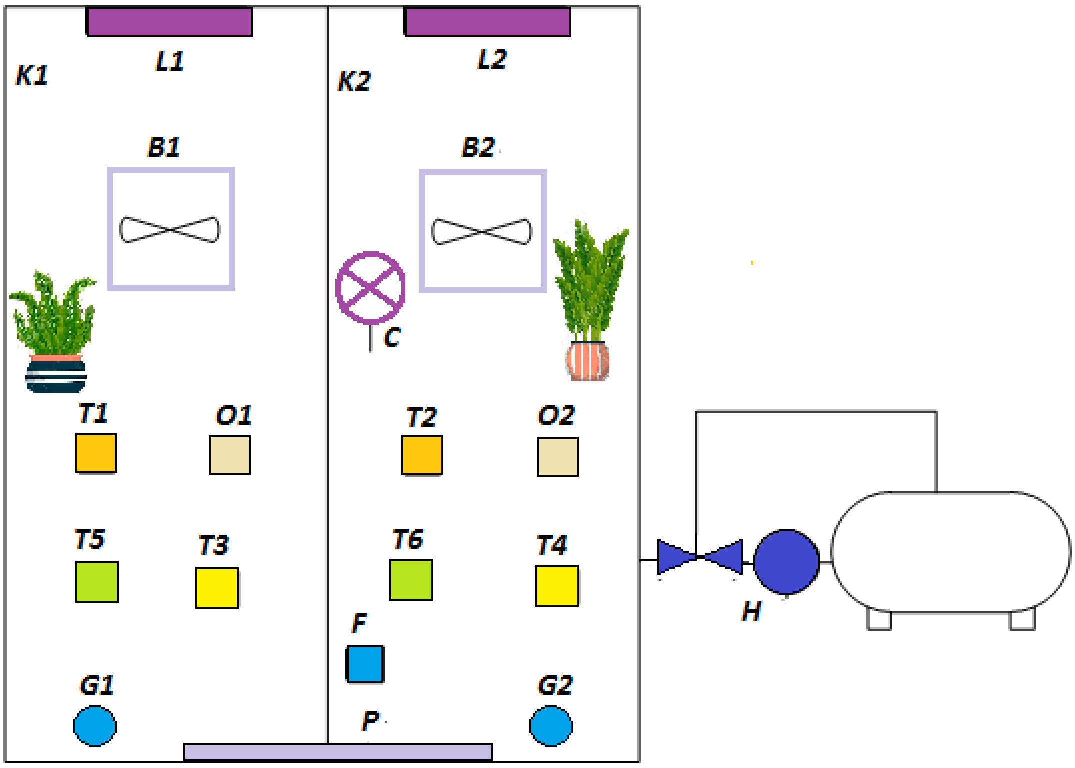

Figure 3: Schematic arrangement of sensors, actuators and regulators

The control of the phytotron electrical complex is divided into three hierarchical levels. The structure of the electrical complex is presented in the following figure (Fig. 4). The phytoclimatic regime is controlled according to the specified cultivation norms, where the daytime air temperature is within 22..25° C; at night - 18..20° C; where the relative humidity should be within 60..70% and air pollution is 350..450 ppm. The control process also provides for the study of the impact of the environment on tomato plants, provides for the additional introduction of phytotemperature criteria for plant development [6], according to which the plant temperature is equal to the air temperature.

The phytotron was mounted in the laboratory of the Department of Automation and Robotic Systems. academic I.I. Martynenko (Figs. 5, 6). The monitoring system is based on the Arduino Uno and the W5100 controller. A web-server was built for graphical display of remote client data, obtaining measured data from temperature, pressure, humidity sensors and the ability to switch the relay to which the devices of the electrical complex are connected (Fig. 7). The server program is written in the Arduino IDE development environment. A Wi-Fi wireless network is also used to allow wireless access to the specified web server. Screenshot of the web server configuration screen show in Fig. 8. When the client requests the server's address in the internal network (http://10.11.0.105), the server contacts the Arduino Uno controller, which forwards the measured data to the browser. The program also provides lighting of the relay switching buttons for switching on and off the components of the electrical complex. Active monitoring of plant development also allows to study the influence of disturbing factors on plant development and the quality of the original vegetable products.

In the project under consideration, the Arduino MEGA2560 + WiFi R3 controller from RobotDyn is used for remote control [23]. In the process of project development, the model "Arduino ESP8266" is used which has all the necessary technical means and external elements for connection (Fig. 1, b). The main idea of using the board is that the switches can be used to configure the interaction of its three components in different ways: the Atmega2560 chip, the ESP8266EX chip, and the CH340G USB-TTL converter [24].

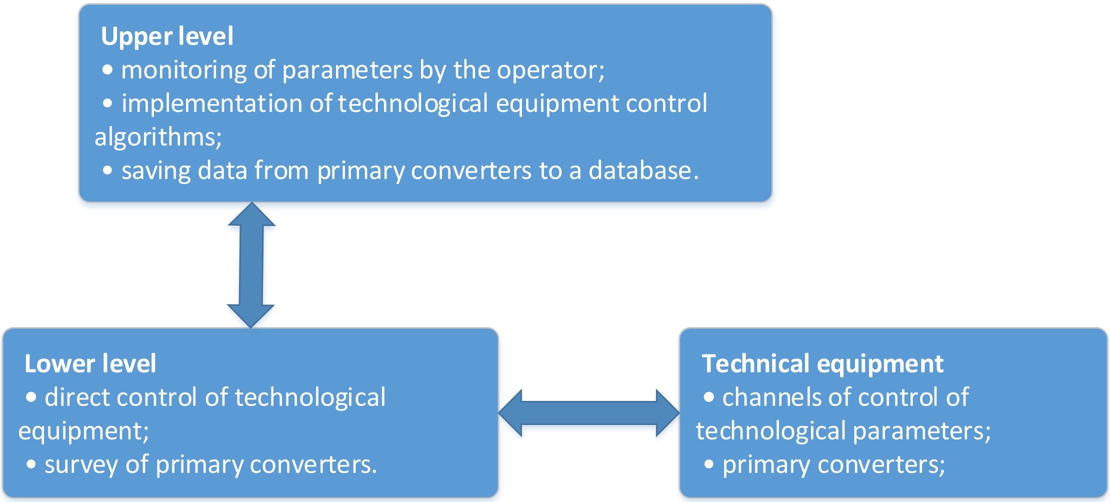

Figure 4: The structure of the electrical complex of the phytotron

Figure 5: Appearance of the workplace of the phytotron operator

5. Discussion

Remote control technologies for other objects are considered by Ukrainian authors N. Kiktev, H. Rozorinov, N. Chichikalo et al. [25]. In particular, the technological scheme of the information-measuring system for determining the ash content of coal has been improved, the algorithm and software interface have been worked out, which will improve the quality of mine coal. The task of creating a video surveillance system based on the state of a mining and technological facility is solved using the example of a conveyor belt in order to further transfer information to the controller.

For decision-making in control systems, the mathematical apparatus described in the work of Ukrainian researchers O. Oletsky, E. Ivohin [26] can be applied, in particular, the evaluation and comparison of alternatives in decision-making problems based on a certain class of matrices and Markov chains.

In the future, the authors plan to conduct a series of experiments in an industrial greenhouse and work out remote control of individual processes using the Internet of things technology.

6. Conclusions

A phytotron model for the study of plant development has been developed and implemented. The structure of the control system has been created, the functional-algorithmic system of the control object has been built and the system of phytomonitoring of plant growing parameters with the use of Internet of Things technology has been implemented.

A web-server was built for graphical display of remote client data, obtaining measured data from sensors of temperature, pressure, humidity and the ability to switch the relay to which the devices of the electrical complex are connected.

Figure 6: Appearance of the phytotron chamber

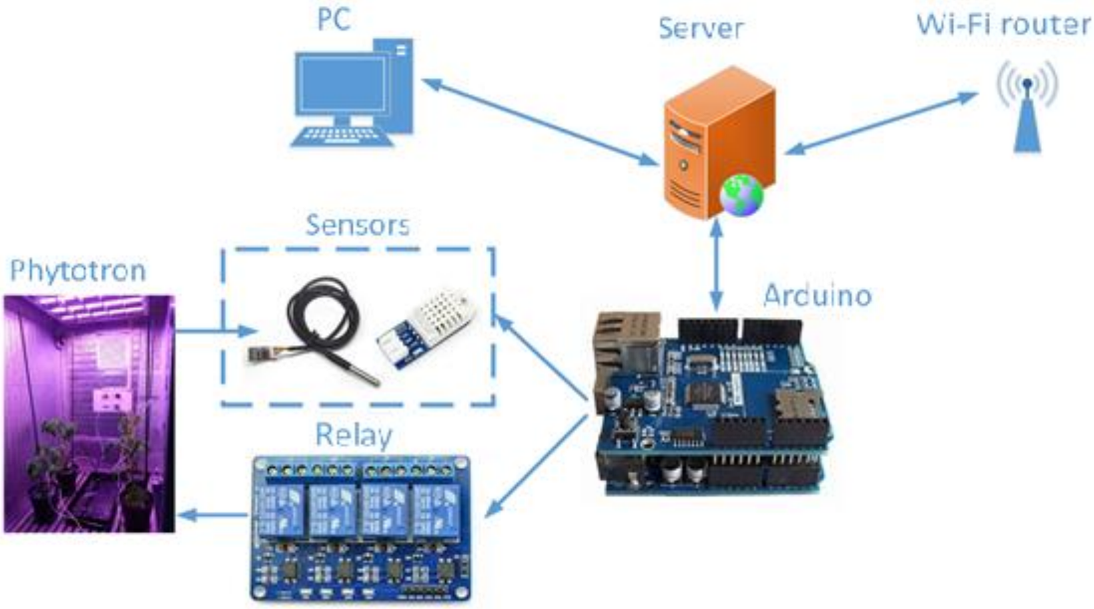

Figure 7: The structure of the control system

Figure 8: Screenshot of the web server configuration screen

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