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Drip Irrigation Cyber-physical System with Remote Control

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ABSTRACT In today's reality, the pace of people's lives is much higher than it was 30 years ago and it is still growing. At the same time, the amount of information is also growing. This information should be processed constantly, daily, as soon as it is received. Production volumes are not also standing still. Such a lively pace of life requires process consistency and continuity and these processes must be provided by a man.

This article describes the system of watering which should automate the process of growing plants. Also, the analysis of a new branch, that is cyber-physical systems, is carried out. The analysis of modern systems of autonomous irrigation, principles of their construction and organization of their work is conducted. A method of implementing a system that provides the possibility of constant monitoring of the growing environment and provides an opportunity to influence it is suggested. The choice of components for system construction is made. The algorithm of the system operation is described. An analysis of the relationship between system components and the user's relationship with the system is performed.

KEYWORDS Autonomous watering; cyber-physical system; microcontroller; remote control; sensors.

I. INTRODUCTION

NOWADAYS, the development of industry directly depends on the automation of production. It is provided by systematic and constant introduction of new technologies into the production process, as well as the development of these technologies. The progress of production and technological processes and their automation leads to the improvement of subsystems that support these processes, namely: timely supply of resources, rapid and uninterrupted execution of tasks, ensuring efficiency, consistency and reliability [1]. As a result, the importance of information increases, which in turn becomes more accurate and able to reflect the processes in their entirety. Such information gives freedom to its owner, because until recently the main component in any process was a human, nothing happened without human intervention.

It's no secret that farming is a rather unprofitable business. One of the main reasons is the time spent on systematic crop care. There are certain rules that owners must follow when caring for plants (watering time and its intervals, volume and temperature of water). Quality watering is a troublesome process. An option to simplify this process is to build a cyber-physical irrigation system that can work remotely and will not require frequent human presence and significant physical exertion. Such systems are integral parts of today's intellectual and later ordinary modern economy.

Cyber-physical system (CPS) is a system that interacts with the physical world, collects information about it and is able to influence it. The basis of the CPSs is the availability of measuring instruments and software that manages them. The US National Institute of Standards and Technology (NIST) defines CPS as follows: “Cyber-physical systems can be defined as intelligent systems consisting of computing components (both hardware and software) and physical components that are jointly integrated and interact with each other to reflect the changing state of the real world. These systems can be of different levels of complexity (both high and low) and can be combined on multiple spatial and temporal scales, and are also connected by a network that combines computational and physical components" [1]. CPS involves transdisciplinary approaches, merging theory of cybernetics, mechatronics, design and process science [2]. CPS is also similar to the Internet of Things, sharing the same basic architecture; nevertheless, CPS presents a higher combination and coordination between physical and computational elements.

These systems are developing rapidly. The US National Science Foundation (NSF) has identified cyber-physical systems as a key area of research [3]. And starting in 2006, the NSF and other United States federal agencies sponsored several workshops on cyber-physical systems [4].

The main purpose of CPS for watering with remote control is automation and simplification of conservative operations. The development of the cyber-physical systems industry is one of the most relevant topics today, the reason for which is the rapid growth of the industry's popularity both abroad and in Ukraine.

A. ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The CPS includes a plurality of nodes that measure and compute the obtained data and interact with the communication environment, which connects them to the means of collecting information (which can perform their long-term storage) and to the means of computing, all this is under the control of security system. The basis for the development of various models of cyber-physical systems is the availability of measuring instruments and their software, which are needed to control the parameters of technological processes and the environment [5].

Unlike more traditional embedded systems, a full-fledged CPS is typically designed as a network of interacting elements with physical input and output instead of standalone devices. The notion is closely tied to concepts of robotics and sensor networks with intelligence mechanisms, that is, computational intelligence leading the pathway. Ongoing advances in science and engineering improve the link between computational and physical elements by means of intelligent mechanisms, increasing the adaptability, autonomy, efficiency, functionality, reliability, and usability of cyber-physical systems [6].

This will broaden the potential of cyber-physical systems in several directions, including:

- intervention (e.g., collision avoidance);
- precision (e.g., robotic surgery and nano-level manufacturing);
- operation in dangerous or inaccessible environments (e.g., search and rescue, firefighting, and deep-sea exploration);
- coordination (e.g., air traffic control, war fighting);
- efficiency (e.g., zero-net energy buildings);
- augmentation of human capabilities (e.g. in healthcare monitoring and delivery) [7].

Cyber-physical systems extend to all spheres of human life. They can be found in any technologically advanced settlement, where there is a constant and intensive circulation of information.

Logistics, energy, manufacturing and many other industries are increasingly using cyber-physical systems. Since these systems accelerate the exchange of information, significantly increase the level of production processes, increase the amount of transmitted information and allow its secure storage and rapid processing, creation of new effective approaches for solving problems and other advantages that together allow not only to improve quality performance and speed up processes, but also to achieve technical progress that can significantly affect the entire economy.

This mechanism is controlled by computer algorithms and is closely related to users.

Watering is a vital stage for the full cultivation and growth of plants. Artificial application of water to those areas that do not receive enough moisture in a natural way allows one to increase soil fertility and provide the most favorable conditions for plant germination. To date, the irrigation system is the most progressive, economical and rational way to deliver water to the lawn, garden, beds for grapes, raspberries, tomatoes, vegetables, strawberries, cucumbers, cabbage, potatoes. This type of watering is provided due to the absorption of moisture by the soil on which water is supplied.

The main advantages of surface irrigation are:

- maintaining constant soil moisture;
- enrichment of soil with oxygen and minerals;
- increasing the supply of groundwater, as water moves deep into the soil;
- the source of water can be a well, a reservoir, a central water supply system or any capacious tank;
- reducing the number of weeds and reduces the prevalence of phytopathology, as moisture comes in doses, and process passages, tracks and aisles remain dry.

Automated irrigation systems are complex devices for regulating the supply and volume of water in order to reduce labor, time and money. Automation greatly simplifies the watering process: the person no longer needs to pull the hose and watering can, manually adjust the pressure and volume of the liquid, and eliminates the need for frequent presence at the planting site [8]. Automated watering has a number of advantages. The system saves water and delivers it to plants more efficiently, water is evenly delivered and distributed throughout the soil. Irrigation occurs in close proximity to plants, and if necessary, water is delivered to the root. Water supply is regulated by the needs of the plants. In this way, the plant receives moisture in a timely manner and in the amount it needs. The supply of water under the root makes it possible to irrigate while maintaining the integrity and decorativeness of the culture. Automatic watering can be configured for the garden and flower garden, and for shrubs and trees, taking into account the characteristics and requirements for watering each of the plants. In this way there will be no waterlogging of the earth or underfilling of water.

Types of watering automation:

1. Fully autonomous system. Such a system is created on the basis of a control module and a plurality of sensors that send signals to the control module about the state of the environment, the control module in turn on the basis of this data turns on or off the actuators. For example, when the soil is dry in a certain area, the control module turns on a relay that starts watering in that area. Watering will be switched off when the sensor is wet. A completely autonomous system works independently and no human intervention is required, but the reliability of this approach and its effectiveness are not high [9].

2. Automated system with the ability to control it. In such a system, the sensors collect information about the environment and transmit it to the operating node. The operating node is able to work independently as a fully autonomous system, and can also communicate with the operator (host) via a GSM module by SMS or other means of communication, and receive appropriate instructions from him through this module. After that, the operating node sends signals to the actuators.

3. Automatic hourly watering. Such a system carries out watering at specified intervals or hours. This system is used for watering lawns. It is easy to implement, but completely ineffective when used for watering "demanding" cultivated

plants, as you need to set up an individual, non-hourly approach to each plant or watering area, which the system does not allow.

An automated control system is the most efficient. The fact is that the owner only needs to obtain information about the state of the growing environment and manually remotely start watering or postpone it, while relying on weather forecast data or personal experience. Also, if the owner is unable to control the watering for some reason, the system will be able to automatically irrigate if this feature is not disabled.

However, such a system has its drawbacks:

- the need for a developed irrigation infrastructure to achieve better results;
- the equipment must be able to work smoothly for a long time;
- the need for constant monitoring of the operation of the irrigation subsystem and the system in general. The reason for this is that one failure equals crop and vegetation loss;
- each culture requires an individual approach. When setting up the system, you have to configure many parameters for different cultures;
- due to the freezing of water in winter, the system can fail if it is not drained (a common disadvantage for all three systems) [10].

B. SYSTEMS OF AUTONOMOUS IRRIGATION

To design an automated irrigation system, it is needed to explore the existing systems that automate this process. Today, there are different systems from different companies, but the choice is not too wide. Also, such systems can usually be purchased only in large specialized stores or ordered.

The most famous manufacturers of irrigation automation systems are: Agras, EuroPoliv, Angio, AquaSmart, Hunter Industries, Cuba [12]. Irrigation systems produced by these companies are in all the previously described types. But all these systems have a common drawback, that is, the price.

Simpler systems, such as Angio, are automatic hourly watering systems, i.e., watering on a timer, which is inefficient in the cultivation of crops. The prices of more functional systems increase sharply as the complexity of the system increases. As the complexity of the system increases, so does the functionality of the system. Thus, Agras system, in addition to the interval watering, is able to perform watering at the specified time and signal the successful execution. Besides, the EuroPoliv system allows one to break a site of watering into separate zones in which irrigation occurs in various, independent time intervals [13-17]

The advantage of more complex systems is that they are quite easy to operate and allow more functionality. As an example, the Hunter Industries system is considered. It allows one to program work cycles: the beginning, duration and end of the irrigation process. When configuring the controller, it prescribes work areas with the appropriate type of watering in each (a total of 12 zones are available). Water begins to enter the pipeline after opening the solenoid valves, driven by a signal from the electronic control panel (controller). The watering rate for the line or individual plants is set on the device. The Predictive Watering function notifies the user of changes in weather and allows you to adjust watering schedules based on temperature forecast, probability of precipitation, wind and humidity, ensuring maximum water savings and keeping plants healthy. The system works without human intervention too.

II. THE PURPOSE OF THE ARTICLE

One of the key features of modern autonomous irrigation systems is the ability to remotely control it without the use of a remote control, as the software of these systems for smartphones allows you to control the main functions of the controller from anywhere where there is Internet access via smartphone or web browser [11]. The user can add an easy-to-install flow meter and set up automatic alerts in the event of pipe or rainwater breakage.

Another interesting development in this field is a system for collecting and analyzing weather data from meteorological stations at local airports or collecting weather information through Internet resources. High level of system efficiency can be achieved by connecting a water flow meter to the system.

The solution proposed in this article allows us to solve the problems associated with the cultivation and care of plants, the main of which is the time spent by the owner. The system also allows us to optimize the watering process and reduce water consumption. It is easy to use and cheap at cost.

Inattentive and untimely care turns into a nuisance for the seedling owner, and often with losses. An irrigation automation system should be used to solve this problem. It is needed to consider the problem of using the cyber-physical system as a means to control the cultivation of cultivated plants and also develop a cyber-physical system for monitoring the growing environment in real time based on analog sensors [24-28].

The main purpose of building the system is to improve the distribution of water consumption and optimize the irrigation algorithm based on weather indicators. The system should be independent of a centralized weather station. Collecting data on weather conditions should be improved to more accurately reflect the situation on the farm and to simplify the process of exchanging information between the user and the device (user experience).

III. STRUCTURAL MODEL OF THE SYSTEM

Before building this system, it should be taken into account that the need to deliver water to crops depends significantly on the weather conditions of the growing environment. It is not allowed to water plants at high temperatures to prevent rot of vegetation, as well as at low temperatures so that the plants do not freeze; it is also better not to water in rainy weather. So, the system must be able to anticipate weather changes. To do this, equip the system with a barometer to predict precipitation, as well as a thermometer to determine air temperature. In this way it will be possible to prevent losses and not to harm plantings.

To solve the problem, a cyber-physical system that can work autonomously and provide the possibility of remote manual control of watering has been designed. For general acquaintance with the device and also for determining the basic functional components of a product and interrelations between them, a structural model of the system is developed. The structural model of the system is presented in Figure 1.

This model shows all the components of the product, the arrows indicate the direction of the processes of information transfer between nodes.

The system consists of the following nodes:

- operating node;
- irrigation control node (electromagnetic relay);

- water tank;
- water pump;
- water dropper;
- communication node;
- device of control;
- atmospheric pressure measuring node;
- soil moisture sensor;
- air temperature measuring node;
- air humidity measuring node.

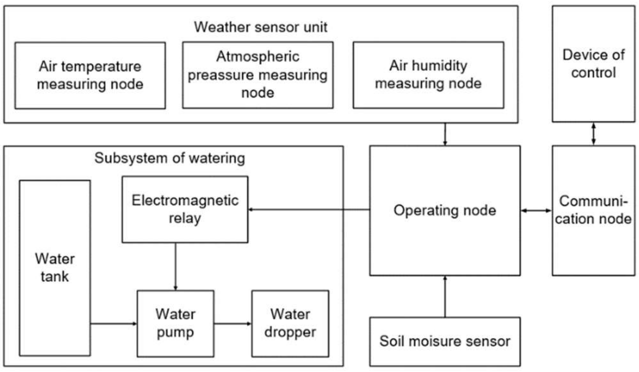

Figure 1. The structural model of the system

The central element of the system is the operational node, which collects information from the nodes on the parameters of the environment and transmits this information to the control device through the communication node.

Nodes of collecting parameters on the state of the environment collect relevant information. This information is transmitted to the working node and output to the control device. A communication node is used to connect the work node to the control unit.

To control the system, the user sends commands through the control unit to the computing unit, which affects the irrigation control unit, which is an electromagnetic mechanism that closes the electrical circuit at the command of the operating unit, that is, relay. Thus, the relay switches the water supply pump from the water tank on and off.

Irrigation management system is a set of hardware and software, which is primarily aimed at efficiency, i.e., to reduce the possible costs (water, time) of the user.

IV. COMMUNICATION WITH THE SYSTEM

The operating node receives information from the measuring nodes about the state of the environment. This information is transmitted to the device of control. Based on this information, operating device of control sends commands to the operating node, which interacts with the irrigation control node; the manual remote watering on / off is carried out in the same way. Between the operating node and the control node there is a communication node that provides transfer of information between these nodes.

To set up communication between user and system, communication node is used. This node can be performed as expansion cards such as GSM modules or Wi-Fi modules as a communication node.

In the first case, the "communication" of the user with the system can be performed by SMS-messages. It is also possible to develop software for communication through popular messengers, such as telegram, which greatly simplifies and speeds up the work and allows more convenient monitoring of actions. In the second case, when implementing communication via the Internet, access to the board is performed through a server on the expansion card. In this case communication is faster than via SMS or messengers like telegram, but such communication is limited to Internet coverage, which is not as common as mobile coverage.

System management and monitoring can be also implemented in the form of a local web server. The main advantage of this approach is that the module works in a closed Wi-Fi network, which is not accessible to any third party. Control can be performed from any device that is connected to this network (mobile phone, computer, tablet) and the number of these devices is unlimited. But you need to be connected to the local network to communicate with the system.

To ensure a good connection, it was decided to use expansion cards to communicate with the system using the cloud service Blynk. Because this service was created specifically for use in embedded systems and the Internet of Things, it is best suited to create a user-friendly interface that can reflect the state of the growing environment much better than text messages or messengers. In Figure 2, the scheme of the system communication through the Blynk service is presented.

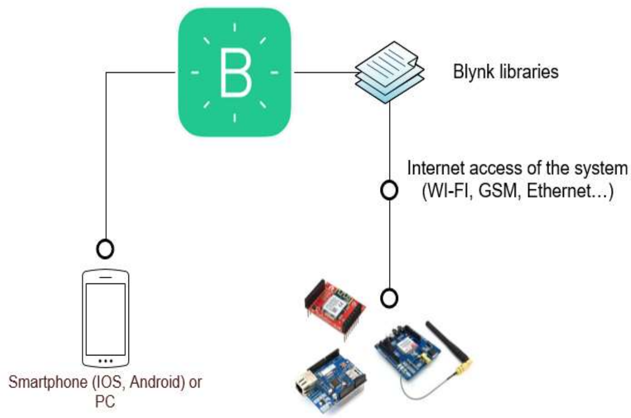

Figure 2. Communication through the Blynk service

V. SYSTEM OPERATION ALGORITHM

The system operates in two modes: autonomous mode and manual control mode. When offline, the system reads environmental parameters and displays these parameters to the user on the control device (smartphone or personal computer), and also controls irrigation based on the data that the system receives from sensors. In manual mode, the system displays parameters to the user but does not water itself. Watering is carried out by the user, while the system must control the watering rate.

On the block diagram of the algorithm in Fig. 3, a list of instructions executed during its operation is shown. The system can water automatically, but only when authorized by the user, that is, when offline mode is enabled. This permission is given to the system via the control device, but reading and output of the parameters will be carried out in any case. When power is applied, the system reads information from the sensors and displays them to the user on the control device. Further, the system does nothing until the user selects an operating mode.

When offline mode is selected, the system reads the data and displays it on the control device. When offline mode is enabled, manual control mode is not available. Next, the system checks whether the humidity indicators are normal, if not, then it checks whether the conditions for watering are acceptable. These conditions can be different: time of day, air temperature, barometer characteristics. If the indicators do not satisfy the watering conditions, then watering will not turn on. Otherwise, watering occurs and will continue until the soil moisture reaches a certain standard mark, after which watering will be turned off.

When manual mode is selected, the system first checks if the moisture readings are acceptable for watering. This is done to insure against possible excessive water consumption, which will lead to excessive soil moisture, and this in turn will lead to the loss of plants. This can happen if the user accidentally turns on watering or if the user does not monitor the system and turn off watering.

When watering is allowed (autonomous mode), the system carries out watering only at the specified parameters. For example, if the soil moisture is above 80 % or less than 20 %, the air temperature is below 8 or above 22 degrees Celsius, and then watering will not turn on.

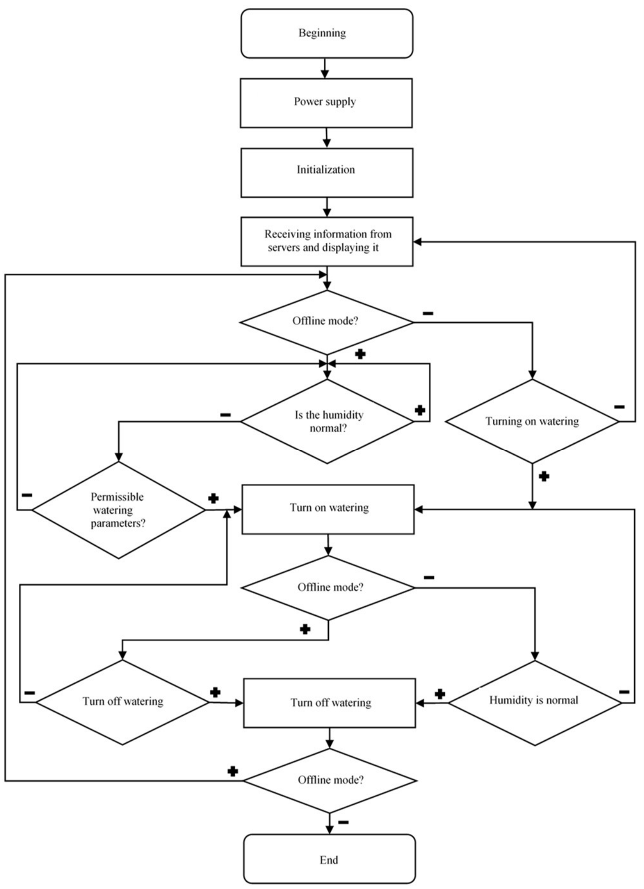

Figure 3. The system operation algorithm

These parameters are given as an example, as the requirements for growing different plants are different. Soil moisture should not exceed 60 ... 70 % of the total moisture content when growing vegetables, 70 ... 80 % - cereals and 80 ... 85 % - grasses.

After turning on watering, the parameters are checked and when the soil moisture limit is reached, watering will be turned off.

The project code is written in a simplified programming language based on C / C ++.

VI. SYSTEM IMPLEMENTATION

According to the functional diagram, the central node requires many I / O ports to work with all connected nodes. To simplify the construction of the system, it would be better to use a microcontroller, which will already have a built-in microprocessor, I / O ports, memory, reset node and synchronization node. It should also be taken into account that we need to use a proven microcontroller to ensure smooth operation.

For more correct construction and research a prototype model is assembled and tested in a greenhouse for growing tomatoes. To implement the product prototype, the Arduino Uno microcontroller is selected as the operating unit of the system. The reason for this is that it has all the above components and is easy to use in projects related to the internet of things and cyber-physical systems.

The microcontroller consists of a computing unit (processor), which is designed for operations with numbers (sequence of such operations-program), a memory module (32 kB Flash (program memory) and 2 kB RAM), which stores the written program and other commands of the microcontroller and I/O ports and also contains a clock generator.

The board consists of 14 digital inputs / outputs, 6 analog inputs, a quartz resonator with a frequency of 16 MHz, a USB connector, a power connector, a connector for programming inside the circuit and a reset button. To operate the device apply power from the AC / DC adapter or other power sources, such as a battery, or connect it to a computer's USB port.

The clock generator (or quartz resonator) is designed to generate a certain number of pulses in one second due to which the microcontroller works. The frequency of the clock generator of the board is 16MHz. This means that the microcontroller is capable of performing up to 16,000,000 operations per second.

The board has a RESET button (built-in reset node). When a reset button is pressed, the microcontroller is moved to the starting position from which it has started its work

Also, this board consumes small amounts of energy even when many other nodes are connected to it. Therefore, it is advisable to use it in systems that work around the clock, as well as it is convenient to use battery-powered.

When the irrigation system works autonomously, without connection to a constant power supply, chargers for phones with 5.5V output power can be used when the Arduino is powered via a USB connector, as well as batteries with a current of at least 500mA or network adapters with output voltage from 7 to 12V when powering the Arduino through the power connector. The Arduino pins output up to 40mA, and the total current that the microcontroller can emit should not exceed 200mA so that it does not burn out.

The Wi-Fi module ESP8266 acts as a communication node. It is a small board with a built-in microcontroller, memory chip, quartz resonator, antenna printed on the board, two LEDs that signal the current status and progress and eight pins for connection, two of which are digital output pins that support latitude -pulse modulation similar to digital Arduino outputs. Thanks to all this, on the basis of this module we can build various projects of cyber-physical systems and the Internet of Things even without the use of other controllers, but together with other controllers (together with Arduino) we can build on much more complex and interesting projects. The maximum data rate is 4.5 Mbps.

The Wi-Fi module ESP8266 allows us to access an operating node through the computer or other means which can be connected to a network. User interaction with the system is realized through a web server thanks to the capabilities of the Wi-Fi module, which allows creating a local web server based on it.

A "Blynk" application is used to display the system status. This application was developed specifically for use in Internet of Things projects. When using the application, working with the system becomes pleasant and easy, as the user does not need to go through authorizations and connect to the local network where the Wi-Fi module is located. The user can also customize what he wants to see in the interface. Connecting Blynk to the system is done during the writing of program code, by connecting the Blynk application to the local network. Therefore, the user will not be able to accidentally disconnect from the system. But when you change the password of the local network, the system will stop responding to requests from the application (such changes are very rarely used). In this way a good level of user experience is achieved.

The system consists of three sensors. The DHT11 sensor is used as two units at once, the air humidity measuring unit and the air temperature measuring unit. This sensor determines the temperature in the range from 2 to 50 ºC. Maximum polling frequency is not more than 1 Hz (1 time per second). The supply voltage of this sensor is 3.5-5.5 V.

The BMP180 barometer is used to measure atmospheric pressure. The measurement range is from 300 to 1100 hPa (9000 ... -500 meters above sea level), control is carried out through the I2C bus, supply voltage 2-5 V.

Capacitive soil moisture sensors are used to measure soil moisture. Soil moisture senso is placed in the soil in close proximity to the plant and watering place and gives an analog signal. The supply voltage of this sensor is 3.5-5.5 V.

Appropriate measuring sensors are connected to the system. The measurement error of all used sensors is less than 2 %.

Using an air temperature sensor and a barometer, we make the system independent of weather forecast services. Based on the indicators of these sensors, we can predict weather changes and also exactly find out the weather conditions at the landing site.

VII. EVALUATION OF IMPROVEMENT

The Hunter system carries out the usual root watering, thus being guided only by indicators of weather conditions and the watering schedule. That is, when the weather changes, the watering schedule is adjusted, watering is postponed until the next day. This approach does not fully meet the needs of the plant, as the weather forecast is not always true, and even if it is true, the rain may not be abundant and may not last long. Thus, the plant does not receive the required amount of fluid.

The proposed cyber-physical system is devoid of such a drawback. Based on weather indicators, watering is postponed for only 1 hour (this time can be changed), after which data is re-collected from the sensors and based on their indicators, a decision is made whether to water the plants or postpone watering again.

Tomatoes are drought-resistant plants, so they should be watered abundantly, but relatively rarely. Usually intervals of 4-5 days are established between waterings. Hunter performs watering according to the schedule and the established doses for each plant. Normal watering rate is 4 liters per plant. The system is set constant dose of watering. Hunter carries out the usual watering under the root of a small watering can attached to the central pipe with water. This system supplies water regardless of whether it is needed or not.

And the proposed irrigation system sets the dose amount independently, based on the indicators of soil moisture sensor. Thus, thanks to the information about the state of soil moisture in the immediate vicinity of the plant, it is possible to optimize the care process much better. Therefore, the system does not pour out excess water, and for a long time moistens the ground to the required humidity of 80 %. For a garden where 10 plants grow, the Hunter system always consumes a constant volume, that is, 40 liters of water per watering, without taking into account the real needs of the plant.

To compare water consumption of systems, we need to compare them under the same conditions. To calculate the volume of liquid used for 1 hectare per hour, we use the equation (1).

$$V = \frac{S}{L * x} \times q, \tag{1}$$

where S – area of the territory, m^2; L – distance between irrigation tubes, m; x – distance between the emitters of the irrigation tube, m; q – rate of outflow of one emitter per hour, *l / hour.*

For the Hunter system parameters are: S_1 – *10000* m^2, L_1– *1.8 m*, x_1 – *0.9 m*, q_1 – *6 l*. Hunter expends *37037 l/hour* on the territory of *1 hectare*.

For cyber-physical system of watering parameters are: S_2– *10000* m^2, L_2 – 1.8 m, x_2 – *0.3 m*, q_2 – *1.4 l*. This system expends *25926 l/hour* on the territory of *1 hectare.*

To find the difference in water consumption, we will use the formula for finding the percentage (2).

$$D = \frac{V_1 - V_2}{V_1} \times 100\,\%, \tag{2}$$

where V_1 – volume of water used by Hunter system, *l/hour*; V_2– volume of water used by designed system, *l/hour*;

Thus, it is determined that the designed system consumes 30 % less water.

The system works in real time mode. Changes in the parameters measured by the system are immediately recorded and displayed through the local web server of the Wi-Fi module and can be read by the user through the device of control. New parameters are displayed to the user and performance of actions accepted from him occurs with a maximum delay in 2 seconds as system nodes need time for information transfer. Since this is drip irrigation, the speed of operations does not play a significant role and a delay of two seconds is not a significant disadvantage. The system reads data from the sensors every 2 minutes. This setting is made in order to reduce the load on the system. Weather changes do not occur sharply, the humidity also changes slowly as drip irrigation is implemented, so this approach is not negative in this case.

Automated watering is carried out drip root for a certain period of time and stops when the soil moisture sensor reaches the maximum allowable soil moisture. Water is delivered through pipes that supply water directly to the planting site. It should also be noted that the system does not carry out watering in case of rainy weather or high humidity. In case the weather conditions do not promote watering and the greenhouse is closed during the rain, watering will start at the lower limit of permissible soil moisture. That is, the control indicator for watering is soil moisture (watering will not begin at high temperatures). It is also should be mentioned that the system can be controlled manually.

The system based on this microcontroller can be expanded, as in the operating unit there are 6 analog inputs, it is possible to add 5 more sensors for measuring soil moisture, so the system can work on six different irrigation zones. In addition, it is possible to add many other sensors to digital inputs and expand the system even more.

VIII. CONCLUSIONS

This article presents the results of working on the designing of the cyber-physical system of watering with remote control.

This system provides root drip irrigation. With this method of watering moisture in the ground lasts longer. Due to this, a gain in water consumption is achieved. Under equal conditions, the designed system consumes 30% less fluid than the compared system.

A new algorithm for plant care is also proposed, which is performed on the basis of collected environmental data. The algorithm works on the basis of soil moisture sensor, temperature and humidity sensor and barometer. Together, this makes it possible to more accurately perform watering based on the needs of the plant, which further increases yields

The components of the cyber-physical system of autonomous irrigation with remote control are described and the choice of components for the implementation of the system is made, the analysis of the interconnection of system components, as well as the user's connection with the system is carried out. The directions of research and application of cyber-physical systems in the field of plant growing are considered.

Designed system measures 4 different parameters: air temperature, atmospheric pressure, humidity, and soil moisture. On the basis of this data, watering in offline mode is carried out and the user is also notified about changes. The work and relations of the components of the irrigation system and user's interaction with it are described. The structural functional models of the system are developed.

Thanks to the use of a barometer and an air temperature sensor, a local meteorological station is implemented, which shows accurate indicators at the irrigation site and not a generalized forecast from Internet services or remote meteorological stations. Based on its indications, the system can decide to carry out watering, and the user can more objectively assess the situation in the irrigation area. The user experience has been improved by using the Blynk smartphone app.

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