Development of an Autonomous System for Control of the Irrigation Regime of Agricultural Production in a Greenhouse

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Abstract— **Water is known to be a chemical compound and plays an essential role in sustaining life on our planet. Fresh water on earth is only 2.5% and the problems with the drought of the regions are known. Therefore, its sparing use will contribute to reducing this effect. This requires the revision of some of the policies of the agricultural sector and the implementation of new and innovative irrigation solutions. Through irrigation and their root system, plants grow and develop. The application of a proper irrigation regime will contribute to a reduction in water use. In this study, an attempt has been made to create an autonomous system for determining and applying the irrigation regime of plants. For this purpose, a greenhouse was used for the industrial production of cucumbers. A soil moisture sensor is used, and the signal is processed by software developed for this purpose, which produces a control signal for the beginning and end of the irrigation process. The process is controlled autonomously, depending on the current state of humidity and when a certain value is reached, the process is terminated. The sensor part is made of standard soil moisture sensors, and the control part is entrusted to a single-board computer with the ability to control via a wireless network.**

Keywords — automatic control, irrigation mode, sensors, agricultural production, greenhouse.

I. Introduction

Climate change is having a serious impact on freshwater systems. Rising sea levels will increase areas of saline groundwater, and this will lead to a decrease in fresh water. An increase in rainfall intensity will lead to flood and drought risks in many areas [1,2,3,4].

Water is an extremely important chemical compound for all forms of life on our planet. It is necessary for the implementation of a number of human activities. Water losses occur in any system and it is necessary to limit them by maintaining their good technical condition. Due to the optimization of the costs of water production and the need to protect water resources, rational reduction of water losses should be a priority [5].

In modern society, one of the tasks of greenhouse vegetable production is related to the performance of social functions aimed at year-round supply of the population with fresh vegetables as a rich source of nutrients necessary to maintain the health and viability of the human body [6,7].

Greenhouse farming has become popular over the past three decades. The controlled environment in greenhouses is an ideal place to grow crops in the off-season and increase their productivity. Greenhouse automation is the appropriate tool for full monitoring and control of the

environment and has a dramatic, social and economic impact. Greenhouses are translucent glass or plastic structures for accelerated cultivation of crops. They allow for more efficient use of water and daylight [8,9,10]. Proper irrigation is key to improving the quality and productivity of crops grown in greenhouses. The time, duration, type and quantity of irrigation are essential to optimize water use. Various irrigation systems can be used, such as: manual watering, top sprinkler system, mobile irrigation boom, flooded floor, drip irrigation, capillary pad and hydroponics. However, drip irrigation is best suited for greenhouses in terms of efficient use of available water. The moisture content of the soil determines the timing of irrigation and therefore continuous monitoring is necessary to decide exactly when irrigation should begin [11,12].

Precise control of the greenhouse environment is crucial to achieving the best and most efficient environment and cultivation efficiency. In the beginning, operating greenhouses was as simple as pulling a circuit to open or close a vent, turning a valve to control heating or irrigation, or pressing a switch to activate a pump or fan. Over the years, this has evolved as greenhouse systems themselves have become more complex and more reliable [9,10].

II. Materials and methods

The development of the modernization system is carried out on the farm of ZP Katya Popova.
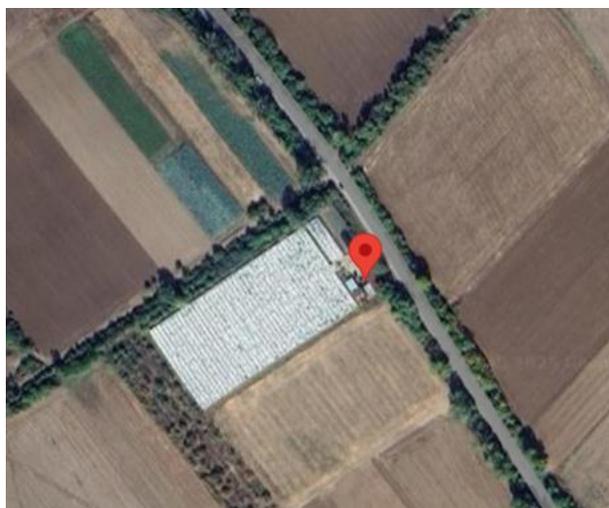

Fig. 1. Satellite photo of the location of the greenhouse.

It is located in the village of Bolyartsi, Plovdiv region, Bulgaria. An old available greenhouse with a drip installation for irrigation is used. The location of the greenhouse is 42°04'24.5"N 24°56'46.5"E (Fig. 1). The automation is done on a glass greenhouse, which is located on an area of 0.72 ha (Fig. 2).

The dimensions of the greenhouse are 60 x 120 m. The structure of the greenhouse is glass with a metal frame. It is divided into two blocks with a path of 2 m between them for loading and unloading activities. The

height of the greenhouse to the eaves is 4 m. The volume of the greenhouse is 28,800 m3. Plant production is grown directly into the soil.

Fig. 2. General view of the greenhouse.

The irrigation system consists of a pump group with suction part 1, safety valve 2, check valve 3, filter group 4, detergent application equipment 5, pressure regulator 10, contact pressure gauge 11, pipe mesh 6-9 (Fig. 3) [12]. Water is extracted from a borehole, through the pumping group. The control of the pumping group is entrusted to the programmer "CEPEX" [13]. It can be used to program the switching on and off of the pumping group in a certain time range, but it cannot control the irrigation regime when the microclimate in the greenhouse changes.
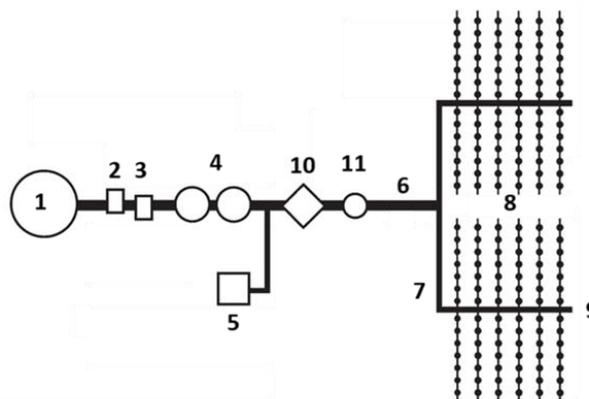

Fig. 3. Scheme of the irrigation installation.

1-pump with suction; 2-safety valve; 3-check valve; 4-filter group; 5-equipment for the application of preparations; 6-transport pipeline; 7-distribution pipeline; 8-drip pipeline; 9-irrigation battery, 10-pressure regulator, 11-pressure gauge

The electrical part of the system is secured by appropriate fuses. The pipe part is secured by the contact pressure gauge 11, the pressure regulator 10, the safety valve 2 and the check valve 3, connected to the outlet pipe of the pump group. It turns on and off the power supply to the pump group when the pressure in the pipe part is exceeded.

The outlet system works when the pump is turned on, the pressure in the irrigation battery 9 is increased and from there it is supplied directly to the drip pipeline 8. If necessary, each battery can be manually stopped.

The culture grown in the greenhouse is cucumbers.

III. RESULTS AND DISCUSSION

According to what has been said so far, it is necessary to approach it in a way with minimal changes to the installation. In accordance with the above, the implementation of automated control of the irrigation regime and water fog for plants in order to obtain sufficient air humidity has been chosen.

The flowchart of operation of the automated system is shown in Fig. 4.

The system relies on two circles. The first round serves to start the irrigation regime from the pipelines for the drops, and the second circle serves for additional dew of the air in the microclimate of the greenhouse. An innovative solution is the installation of a second controllable circuit for the water fog system with humidity control.

The logical part of the automated system is implemented by the single-board controller ESP 32 [14]. Each controller is equipped with the separate air humidity and soil moisture sensors for each row. Each controller produces a control signal to the executive units.
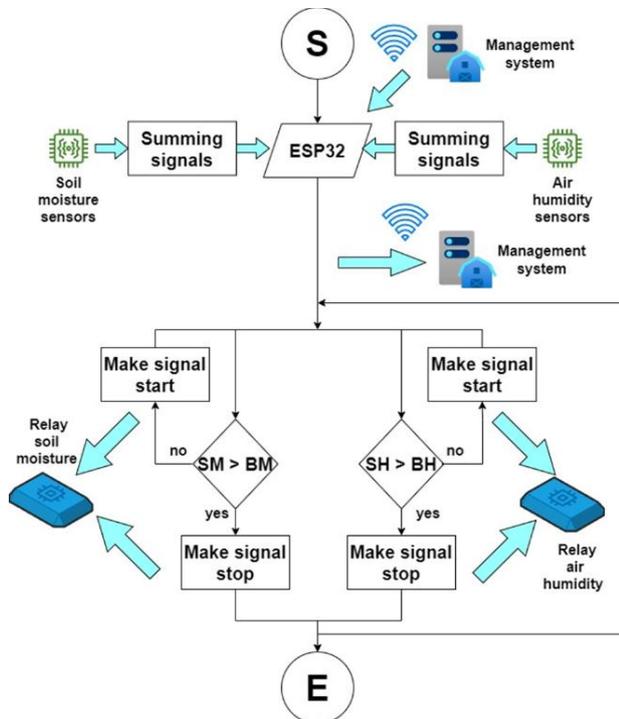
Fig. 4. Flowchart of the operation of the automated system.

Fig. 5. Data from analog inputs.

The ESP 32 receives instructions for the values of the monitored parameters via wifi and a special data transfer protocol. Through the ESP 32 protocol, it communicates with a central computer with user software installed. A request for the required soil moisture and air humidity is sent. The current values measured by the sensors are sent to the user software. They can serve to analyze the veracity of the decisions made. The computer and ESP 32 can work on different networks. The data refresh is every minute.

At the length of each row of the greenhouse of 29 m, four HD-38 sensors were used for two rows to determine soil moisture, located at an even distance from each other [15,16]. According to the design of the greenhouse and the heating installation, the rows are paired. In the greenhouse, there are 40 paired rows in each field. The staggered arrangement of the sensors in both rows is appropriate, thus shortening the number of sensors. The distance between two sensors varies between 7 and 8 m. Three DHT-22 sensors are used to determine the air humidity for every two rows [17]. They are located evenly from each other and in a checkerboard pattern in the space above the plants (Fig. 5), with a distance between them in the range of 9 to 15 m.

With these sensors, the irrigation regime and water fog of each individual row can be controlled. Depending on its distance, a transmitter is installed to each sensor. It prevents signal attenuation.

The actuator in the system is a controllable relay through ESP 32, which turns on or off the power supply to the MV07 solenoid valve (Fig. 6) mounted on the drip pipeline immediately after the irrigation battery [18]. The valve stops and releases water from the irrigation battery to the drip line. For the current development, two valves are needed every two rows - one for the drip pipeline and one for air dew. The drip pipeline has been redesigned, and a triple distributor is connected to the outlet of the solenoid valve, supplying both rows at the same time. Unused outlets from the irrigation battery are closed. For reliable operation of the controller, it is

necessary to use additional power relays to control the valves.

Fig. 6. Sample version of a solenoid valve.

The use of a wifi connection for communication between the individual ESP 32 and the control computer is a suitable option due to the large volume of communication devices and reduced the cable installation. Additional amplification of the network signal is required due to its attenuation in the greenhouse. A router with appropriate parameters is also needed. It is important to note that the exposed elements of the system operate in high humidity and must be provided with an appropriate degree of protection.

The control software has the ability to turn the system on or off entirely. This is achieved by additional controllable relays via wifi. One relay controls the switching on and off of the power supply to the pump group, and the other relay supplies supply voltage to the ESP modules. They are powered via a wired network from the controlled wifi relay. When the system is initialized, a control signal is generated to turn on the two relays.
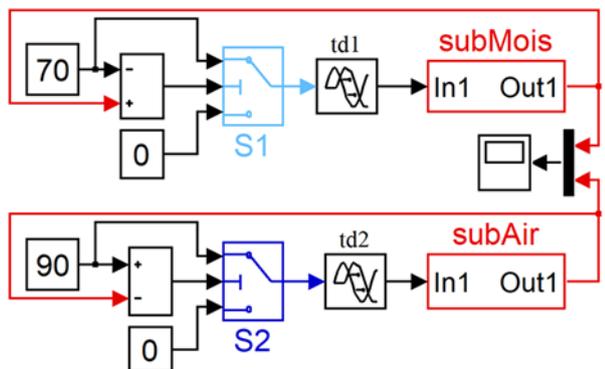

Fig. 7. Logic Element Simulation Model for Each Row.

According to the scheme of work from Fig. 4 ESP32 collects data from soil moisture and air humidity sensors. Because the sensors are located along the entire length of the row, they feed information at the same time. ESP 32 processes the information and creates average values for

soil moisture SM and air humidity separately SH. At the same time, information about the desired values of these parameters BM and BH is received via wifi via wifi. In a constant cycle, the control algorithm in ESP 32 compares the two values SM to BM, as well as SH to BH. The logic conditions are SM>BM and SH>BM. In case of failure to meet any of the logical conditions, a control signal is generated to connect the corresponding command relay connected to ESP 32 and the cycle is repeated. The repetition of the cycle continues until the logical condition is positively met, after which a control signal is generated to turn off the corresponding command relay. The two cycles run in parallel and independently of each other. After either of the two cycles is exited, the ESP 32 system returns to the beginning of the logical conditions and the comparison of values begins again. The process is continuous until the power supply to the system is interrupted by the signal of the control computer for the system. Before starting a comparison of the average value with the baseline, ESP 32 returns to the control computer the corresponding current average value. In the user software, it is possible to monitor each value of the respective ESP 32 and set its threshold values. Thus, it is possible to autonomously adjust the parameters of each of the rows of the greenhouse.

The logical part itself is executed according to the simulation model shown in Fig. 7. It is implemented in the memory of ESP 32.
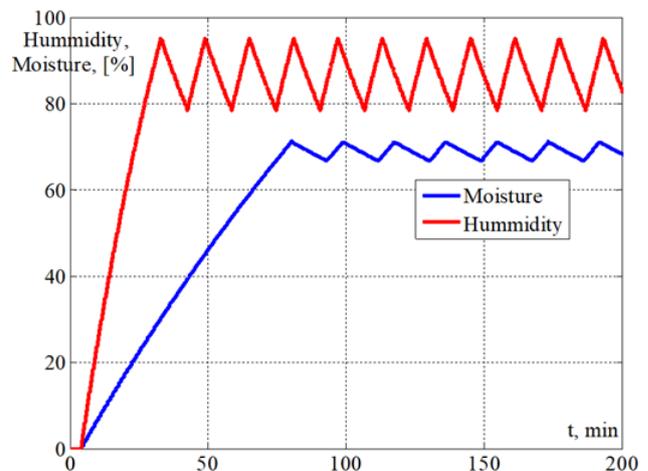

Fig. 8. Sample time diagram of the simulated controlled process.

With the blocks td1=4min and td2=4min, the transport delay from the moment of switching the relay to the flow of the drop or the mist is obtained. The blocks S1 (u2>threshold=2) and S2 (u2>threshold=5) are the logical keys that switch. S1 is responsible for soil moisture, and S1 is responsible for air humidity. The hysteresis for soil moisture is 2, and for air humidity 5. The system is closed with feedback. The signal from the average value of the respective SM or SH sensors of the ESP 32 is fed at the feedbacks. At position 70, the base values BM for soil moisture are set and for air humidity BH is given to position 90. The object of control soil or

air is generated by the two blocks sub. During the recalculation in them, the volume of air in the greenhouse and the area of the surface layer of the soil are taken into account. The control generating signal is taken from the oscilloscope.

In figure 8 shows an example of the simulated process of regulating air and soil humidity for a time of 200 minutes.

IV. CONCLUSIONS

An existing irrigation installation has been converted into a greenhouse with elements of automatic control of the irrigation regime depending on the humidity. The rework includes the replacement of the control relay of the pump group, the rework of the irrigation batteries and the installation of an additional pipe mesh for water fog.

The addition of a sensor network to the existing ESP 32 controller system helps to accurately determine the humidity in different areas of the greenhouse. In addition to soil moisture sensors, air humidity sensors are also used. Through them, the necessary microclimatic conditions for growing plants are achieved.

The simulation of the control algorithm shows the stability and autonomy of the controlled process. An opportunity has been created for the integration of additional control processes. They are not part of the object of current development, but can be used in future developments. Such are control of ventilation in the greenhouse, lowering the temperature of the surface of plants through water fog, etc.

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