Monitoring and Control of the Greenhouse Using Remote Control Device and IoT

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Abstract- The production in protected areas requires a lot of work to create and to maintain the microclimatic conditions for plants to grow healthy and fast. To solve this problem automated systems are used. This paper proposes an automated system for controlling and monitoring microclimate conditions in a greenhouse. This system operates automatically and the user monitors its operation and if necessary remotely changes the individual system parameters. A remote control device, that is designed and programmed, is working on an independent WiFi network. A remote control device has been designed to change values to essential parameters. Essential parameter for plant growth are temperature, air quality, soil moisture light and etc. All the essential parameters for the growth of plants inside the greenhouse are also sent to the cloud using a local WiFi network. For easy access to this information, a website has also been created. The user is also enabled to change the microclimatic conditions inside the greenhouse through the website and through the cloud.
Keywords – ATMega2560 microcontroller, Cloud, Greenhouse,IoT, NodeMCU (ESP8266 WiFi module), ThingSpeak

I. INTRODUCTION

Production in open fields is becoming increasingly difficult due to unstable weather with sudden temperature fluctuations, heavy droughts and heavy rainfall accompanied by hail [1]. As a result, there is a growing need to grow plants in greenhouses. In B&H, greenhouse production is still in the development phase, but it can be noticed that more people are expressing the need for fresh fruits and vegetables and their availability throughout the year. The greenhouse can be automated and thus relieve the user of the day-to-day obligations for maintaining optimal conditions in the greenhouse. In an automated greenhouse, the user can, regardless of their location, through a computer or other smart device, control the brightness, temperature, soil humidity, and air quality [2]. LED lighting is used as an alternative light source because different wavelengths of light produce different levels of energy that plants absorb[3][4]. In this paper is proposed the design and implementation of the greenhouse using a remote control device and IoT. In this paper is used the Arduino open-source platform to program the ATMega2560 microcontroller. The Arduino is a microcontroller board with an Atmel microcontroller and additional parts needed to operate the microcontroller and external connectors for easy connection of external elements [5]. Communication was performed using a wireless WiFi network. Like every communication network, WiFi also involves transmitter (Wireless Router/Hotspot) and receiver which can be any Wifi-enabled device like laptop, mobile, tablet, etc. WiFi network is convenient, flexible, and easy to use [6]. All of the data that the sensors read in the greenhouse model, which reflect the current state, will be able to be monitored by the user via the cloud. For this purpose, the ThingSpeak is used. ThingSpeak is an open-source Internet of Things application and API to store and retrieve data from things using the HTTP and MQTT protocol over the WiFi or via a LAN. All data from the cloud are pulled to the Web page. This Web page is designed for easier user interaction with the projected system. The Web page is enabled to set desired values that will be sent to the projected system. Also, the remote control device is designed and programmed. This remote control device receives all of the data that the sensors read in the greenhouse and display them. The user can set desired values for the parameters and those will be applied in the greenhouse system. Also, an experimental work analysis of the proposed system is performed.

II. IMPLEMENTATION AND DESIGN OF THE PROPOSED GREENHOUSE SYSTEM

The proposed system is implemented in the greenhouse model which is shown in Figure 1. The size of the greenhouse model is 162cm x 60cm. The greenhouse model is made from wood and special transparent foil. The construction of the greenhouse model is secured by a metal batten. The greenhouse model consists of four separate parts for planting different types of plants. In addition to temperature, lighting and air quality in each part of the greenhouse model is to maintain a different level of soil moisture. Based on the obtained values of the mentioned parameters, monitoring and analyzing of plant growth is performed.

Figure 1. The greenhouse model

The functional block diagram of the proposed system is shown in Figure 2.

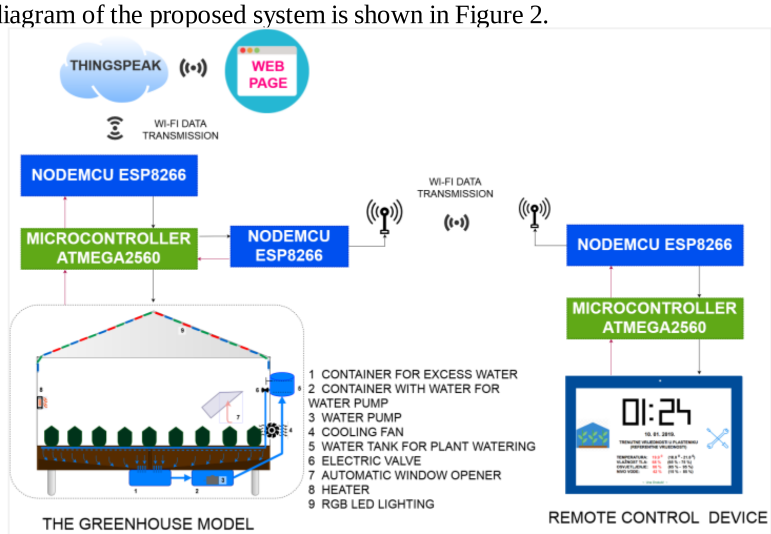

Figure 2. The functional block diagram of the proposed system

From Figure 2 we can see that the proposed system consists of several subsystems. These subsystems are:

1. Watering subsystem,
2. Lighting subsystem,
3. Temperature control and air quality subsystem,
4. Remote monitoring and control using remote control device subsystem,
5. Remote monitoring and control using IoT subsystem.

2.1. The watering subsystem

The watering subsystem is used to supply water from a distant location. The water tank is located above the greenhouse model. This complex system was implemented using a water pump to supply water from a distant location, level sensors to control the level of water in the water tank, soil moisture sensors that are distributed in individual parts of the greenhouse model and tubes for autonomous operation of the watering system. The functional block diagram of this subsystem is shown in the Figure 3.

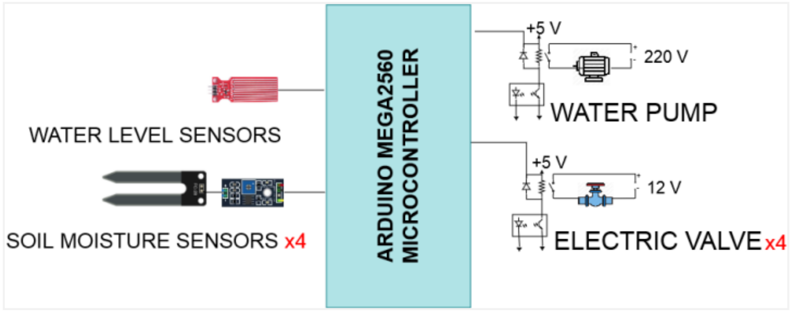

Figure 3. The functional block diagram for the watering subsystem

In Figure 4 the block diagram of the watering subsystem with the indicated electrical components is shown. By using the remote control device or using the designed web page, the user inputs the desired soil moisture and the proposed system maintains the set values for soil moisture at that level. Feedback on the real soil moisture is sent to the cloud and the created web page and to the remote control device. In this way, the user has at all times the true values of soil moisture in individual parts of the greenhouse.

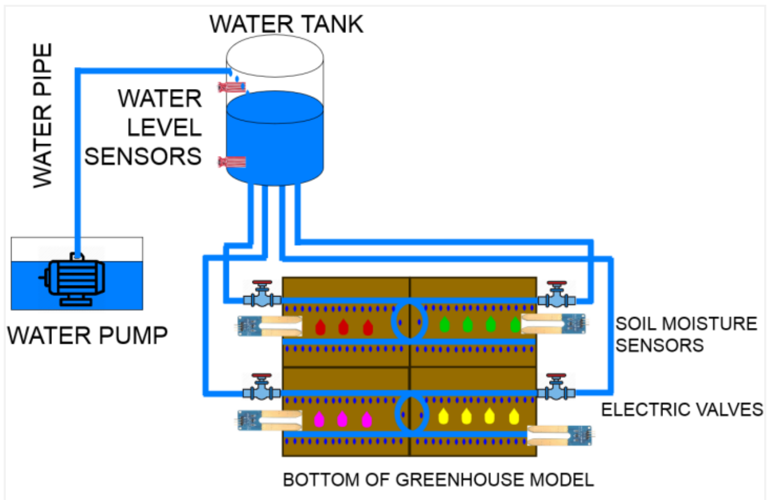

Figure 4. The functional block diagram for the watering subsystem with components

2.2. The lighting subsystem

The proposed subsystem monitors the brightness inside the greenhouse model using a photoresistor. When there is "enough" daylight, the lighting is off. In case daylight is not enough, the lighting of the RGB strip is on. The electrical scheme of the lighting subsystem is shown in the Figure 5. To get the highest yield, RGB leg lighting was used with led strips of red green and blue colors [9]. Each of these colors has a positive effect on the growth of individual plant types.

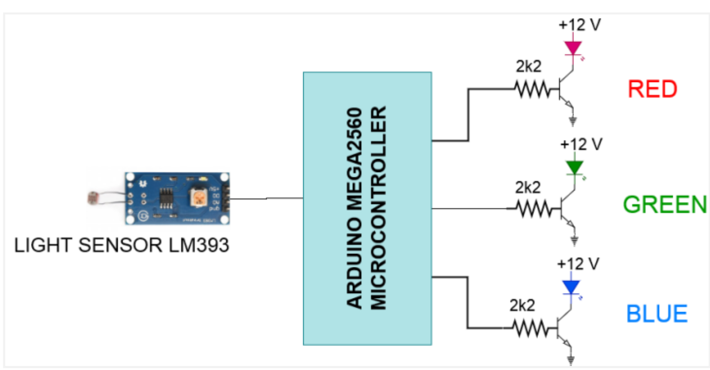

Figure 5. The functional block diagram for the lighting subsystem

Each type of plant reacts differently depending on the color of the light it absorbs. Advanced LED technology allows people to control the strength and the color of light. The lighting subsystem is realized in the greenhouse model to encourage fast growth and higher yields. Used colors in this system are red, blue and green. These colors are used because of their effect on the plant. The level of light in the greenhouse model depends on the level of the daylight. RGB led light is brighter if daylight is darker. In this way plants in the greenhouse get the required amount of light. The light color that provides the most energy is on the ultra purple end of the spectrum of colors. Purple lights have short wavelengths which mean higher energy. At the end of the spectrum of colors is a red light. Red light has long wavelengths which mean lower energy. The green light has a calming effect on plants because it is the color of their pigment of chlorophyll. Because of that green light does not affect the energy level in plants. Blue light helps to stimulate vegetative growth and leaves growth. Red light combined with blue light allows the early flowering of plants. Knowing that different colors of light can affect how a plant grows people can make the most from plants.

2.3. The temperature control and air quality subsystem

For each plant, there is an optimum temperature range for which maximum results are obtained. However, in many cases, we cannot achieve this without high energy consumption. In this case, the cost-effectiveness of such a subsystem is highly questionable.

In our case (see Figure 6), the temperature control is performed in a way that the user sets the desired temperature. The system heats up on the basis of the thermal values. If the desired temperature is higher than the real temperature the window on the greenhouse model is open and the cooling fan is turned on. The air quality in the greenhouse model is very important for the growth of plants. In daylight, plants use carbon dioxide for the process of photosynthesis. When daylight disappears, activation of process where plants take in oxygen that they use to break down sugar into energy, releasing carbon dioxide. In the proposed greenhouse model this is solved using the MQ2 gas sensor.

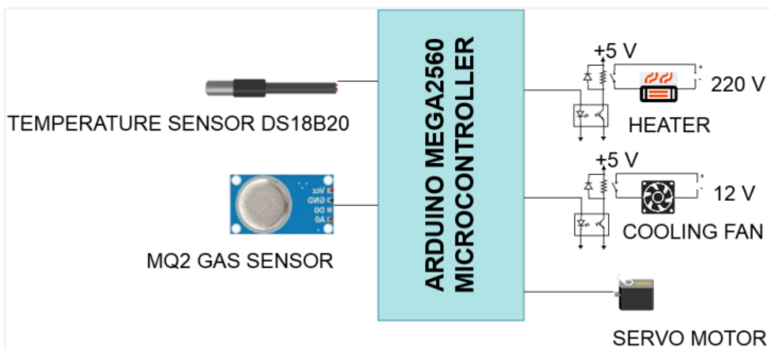

Figure 6. The functional block diagram for the temperature control and air quality subsystem

If the MQ2 sensor reads lower value then the value which the user had set for air quality, then the cooling fan and the servo motor will turn on. Servo motor opens the window. After a while, when the value for air quality is in the desired range the cooling fan and servo motor will turn off.

2.4. The subsystem for remote monitoring and control using remote control device

Modern trends in today's world is connections as many devices and as many systems as possible to the Internet. In this way, the systems can be remotely monitored, controlled, analyzed or adjusted by the important parameters of the system.

The remote monitoring and control subsystem is realized using a screen touch 3.5-inch display which is programmed. This display has the purpose of a remote controle device. The remote control device is connected to the Arduino board with microcontroller ATMega2560 and presents a client-side of communication. On the server-side of communication is the Arduino board with microcontroller ATMega2560 which is programmed to control the designed greenhouse system. These two Arduino boards are communication over wireless WiFi networks using NodeMCU ESP8266 communication modules, as shown in Figure 7.

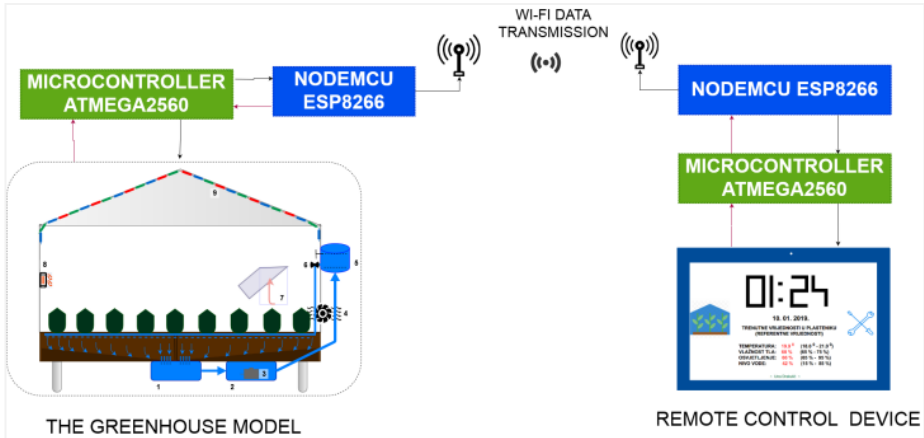

Figure 7. The functional block diagram for the remote monitoring and control subsystem

The proposed system, the system for remote monitoring and control of microclimate conditions in the greenhouse model is connected wirelessly, using the NodeMCU, to the global Internet. NodeMCU is an open source Lua based firmware for the ESP8266 WiFi SOC [7]. The collected data is saved to the cloud (ThingSpeak platform). Using the Webpage (designed for the proposed system), the collected data in the cloud is passed to the users. On the other side, the user is allowed to change the important parameters in the greenhouse model using the designed web page. The parameters that the user enter are sent from the web page to the cloud, and from the cloud to the designed system for remote monitoring and control of microclimate conditions in the greenhouse model. This allows the user to monitor and control the proposed system from any location in the world that has Internet access. In the Figure 8 is shown the remote control device. The remote controle allows the user to be away from the greenhouse system. The user has access to all relevant data and can set the desired parameters in the greenhouse. The remote controller is shown in Figure 8.

Figure 8. The appearance of the emote control device

In Figure 8 is shown the remote controller device. The main window is shown in 8.a., the password window is shown in 8.b. and in 8.c. is shown the menu window.

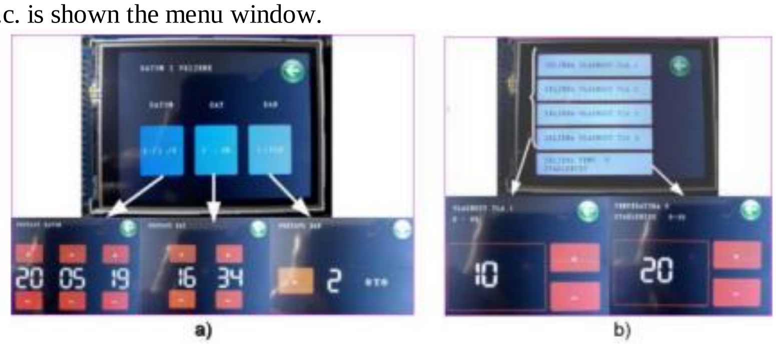

Figure 9. The appearance of the menu window

In Figure 9 is shown the menu windows, where 9.a. shows time and date settings and on 9.b. shows greenhouse parameter settings. After desired values are entered, all data are saved in EEPROM memory in microcontroller ATMega2560. All entered data, using Wi-Fi wireless network, are sent to Arduino board with ATMega2560 microcontroler in the greenhouse system. The distance of the user from the greenhouse system can be several hundred meters depending on the current conditions [8].

2.5. The subsystem for remote monitoring and control using IoT

From Figure 10 we can see that the user can use the remote control device to monitor the current conditions in the greenhouse model, to set new values of essential parameters for plant growth from a distant location. The WiFi network formed to communicate with remote control devices in the greenhouse model is independent of the external WiFi network and connections to the global network Internet.

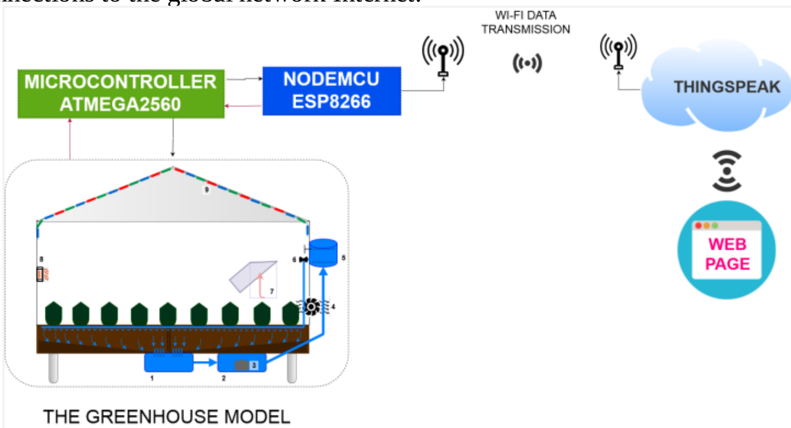

Figure 10. The functional block diagram for the remote monitoring and control subsystem

This system is realized using Node MCU esp8266 module which is connected to Arduino board with ATMega2560 microcontroller in the greenhouse system. Node MCU esp8266 model, using a Wi-Fi wireless network, sends received data to the cloud. For this purpose is used the ThingSpeak platform. Also, we have designed a Web page that pulls all data from the ThingSpeak platform. On the Web page are shown all parameters with received values in real-time with the possibility to add desired value to a specific parameter. In figure 10 is shown the functional block diagram for IoT subsystem.

This subsystem enables data monitoring in the greenhouse system for a longer period of time as well as an overview of all relevant data from any location in the world that has access to the Internet. Because this subsystem is based on the use of wireless Wi-Fi network, it is important that there are no physical gaps that would significantly reduce the power of the Wi-Fi signal.

III. EXPERIMENTAL WORK ANALYSIS FOR THE PROPOSED GREENHOUSE SYSTEM

For experimental analysis, we changed the desired parameters and monitored the response of the projected system. First, we set the desired temperature to 19 degrees on the remote control device. The current temperature in the greenhouse model is 22 degrees. After a few seconds the cooling fan is turning on and the servo motor opens the window. After a short time, the temperature in the greenhouse model dropped to 19 degrees. In case the projected system cannot reach the desired temperature, because it doesn't have an artificial cooling system installed, the projected system will turn off the cooling fan and close the window after reaching the minimum possible optimal temperature and will continue to maintain that temperature. The finished appearance of the proposed greenhouse system is shown in Figure 11.

If we set the desired temperature to 25 degrees. The projected system turns off the cooling fan and closes the window, and turns the heater on. When the desired temperature is reached, the heater turns off and the system maintains the given temperature.

The user can also set higher soil humidity in the desired parts of the greenhouse model. In our case, the desired soil humidity is 45% and the current soil humidity is 33%. After setting the desired soil humidity, the projected system opens the electric valve and the soil humidity inside the greenhouse model began to rise slightly. When the soil humidity rises up to 42%, the electric valve turn off. The soil humidity continued to rise slower until soil humidity is 45%. If less soil humidity is desired than the current soil humidity, the projected system will not respond. A possible scenario for future work, in this case, is to turn on the heater and the cooling fan to reduce soil humidity. The actual soil humidity and the temperature inside the greenhouse model are sent to the cloud and further to the web site. Other subsystems were also tested and gave satisfactory results.

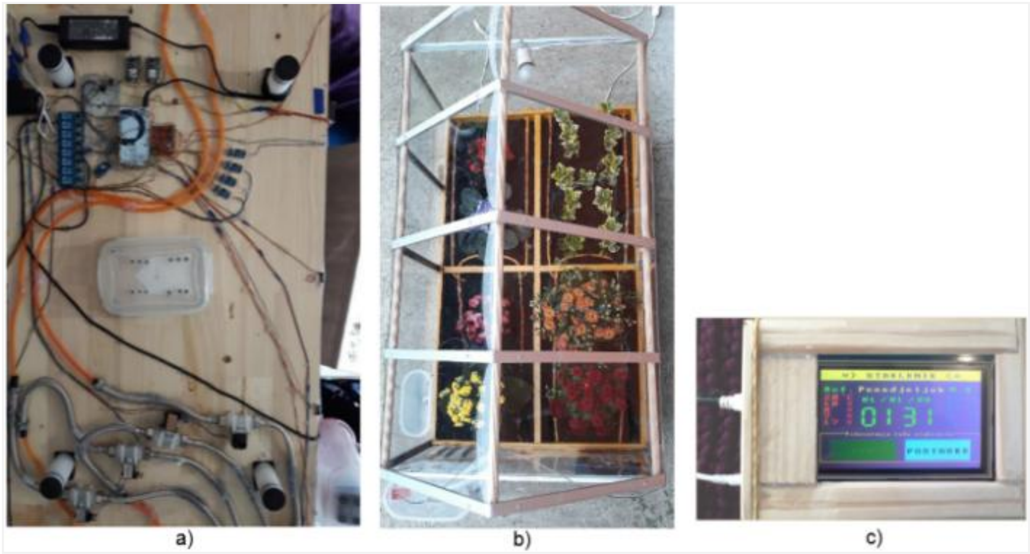

Figure 11. a) Hardware (bottom side) of the greenhouse model b) The finished appearance of the proposed greenhouse system c) The remote control device

On the Figure 12 is shown the appearance of designed ThingSpeak channel with obtained data and on Figure 13 is shown the appearance of designed Web page with obtained data.

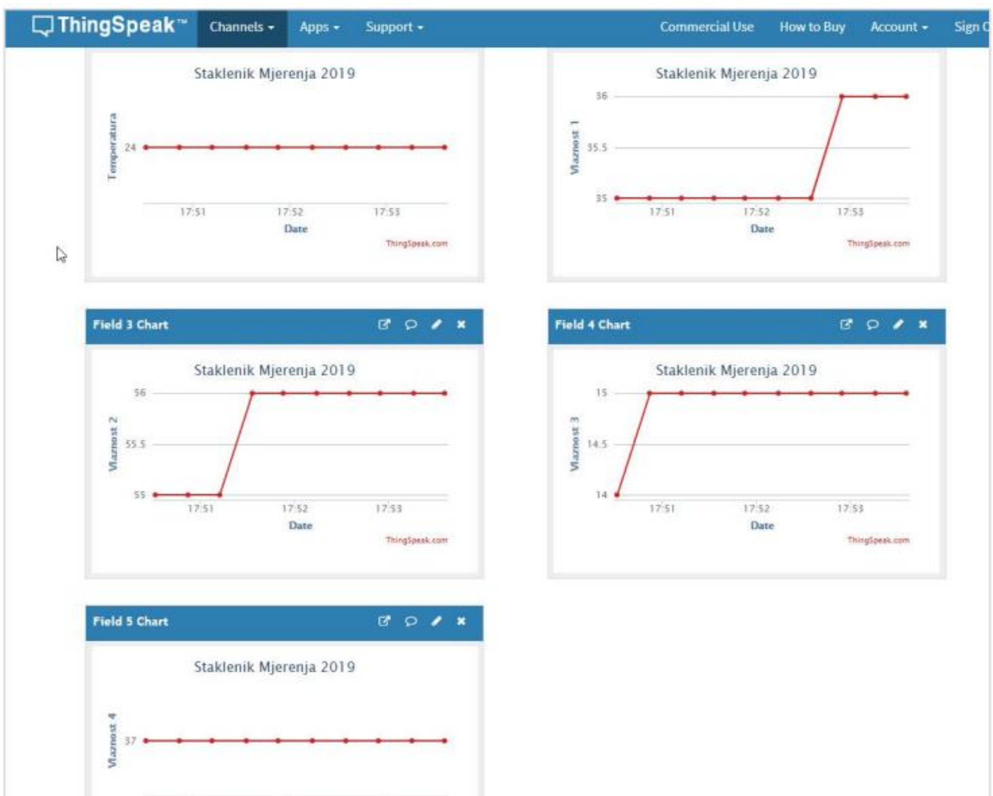

Figure 12. The appearance of designed ThingSpeak channel with obtained data

Figure 13. The appearance of designed Web page with obtained data

IV.CONCLUSION

Based on experimental analyses we can conclude that the proposed system is working properly. Also, we can conclude the projected system for remote monitoring and control microclimatic conditions in the greenhouse model with minimal change can use for remote monitoring and control in the real greenhouses.

V. REFERENCES

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