Remote Monitoring and Control System for Greenhouse Based on IoT

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Abstract. Nowadays, the need for greenhouse production is growing more and more. This is affected by global climate change with high temperature oscillations, as well as an increasing number of natural disasters that can partly or completely destroy production on open fields. In addition, greenhouse production provides constant yields (fresh fruits, vegetables etc.) during the whole year. However, if the greenhouse is not well designed the yields from greenhouse production are declining considerably. This is the case with most greenhouses in B&H. Therefore, it is necessary to design the system that will maintain optimum conditions in the greenhouse with minimum energy consumption. In this paper is designed the greenhouse (greenhouse model size 120 × 60 cm). The microclimatic conditions in the greenhouse model are approximately the same as the real greenhouse conditions. Several types of plants in the greenhouse model are planted. The system is designed to control all important parameters in the greenhouse with minimal energy consumption. To control the parameters inside the greenhouse, the remote controller with touch 3.5 inch display is designed. This way is enabled for all users who are allowed access to review, analyze and make certain conclusions about the work of the greenhouse. Also, all relevant information about microclimate conditions inside the greenhouse model are sent to the cloud (IoT). In this way, remote access to all relevant data on microclimatic conditions in the greenhouse model is enabled, as well as analysis of the same.

Keywords: Greenhouse · Internet of Things · NodeMCU ESP8266 · Remote control · Energy consumption · Microcontroller

1 Introduction

Production in a protected area is an important and fast growing component of the agricultural industry [1]. In B&H, this production is still in development, but it can be noticed that more and more populations have the need for this type of production.

Protected areas are usually made of glass. In recent times, a greenhouse plastic film for the archive greenhouse effect is often used [2]. In this case, the growth of plants is affected by: the thickness of the greenhouse plastic film, the permeability of the amount of light and the possibility of heat retention.

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The permeability of the amount of light is essential for plant growth. Clear greenhouse plastic film is used for growth lower plants because they require direct light.

While the diffusion greenhouse plastic film is used for the growth of higher plants. For these plants, scattered light is suitable. Diffuse greenhouse plastic film reduces sunburn and the temperature inside the greenhouse. In addition to these there are anti-condensing greenhouse plastic films to prevent condensation inside the greenhouse [3].

In the greenhouse, essential parameters can be controlled for creating optimal conditions for plant growth such as: temperature, lighting, airing, watering, etc.

In the opinion of experts, primarily economists and agronomists, it is necessary to construct and equip one or more greenhouses of at least 1000 m^2 of arable land, in which intensively produce fruit, vegetables and /or flowers all year round for economically cost-effective production [4].

For easier production, the greenhouse can be automated. In this way, the user of day-to-day duties is released, which are crucial for maintaining optimal conditions in the greenhouse. In automated greenhouse, the user can, regardless of his location, use a computer or some other smart device to control the lighting, temperature, soil moisture and air quality [5].

All relevant information about the microclimate conditions in the greenhouse are sent to the cloud (IoT). The reason for this is easier data availability and analysis of the same [6].

The greenhouse allows us to control lighting in greenhouse (duration and type of lighting). In addition to the sunlight, alternative light sources can be used to provide ideal conditions for plant growth [7]. One of these alternative light sources is LED lighting. The use of LED lighting in greenhouses was first presented in USA 1991. LED lighting has low energy consumption and gives light frequencies that are suitable for growing “useful” plants in the greenhouse [8]. Also, studies is shown how insects could be detected and expel from the greenhouse by using LED lighting [9].

In this paper an automated greenhouse system is proposed for control of all relevant microclimate conditions in the greenhouse.

2 Design and Implementation Remote Monitoring and Control System for Greenhouse Based on IoT

In this part of paper is described design and implementation remote monitoring and control system for greenhouse based on IoT. For easier implementation of the projected system, the model of greenhouse is made. Model of greenhouse is made from wood and special transparent foil. For the construction metal batten is used. Model of the greenhouse is shown in Fig. 1.

The greenhouse model consists of four separate parts for planting different plants. In every part is maintain different level of soil moisture. Based on this, the growth of plants is monitored and analyzed.

Fig. 1. Model of the greenhouse

2.1 Automated Control Greenhouse System

Automated control greenhouse system is designed to control microclimatic conditions in the greenhouse model. The functional block diagram of projected system is shown in Fig. 2.

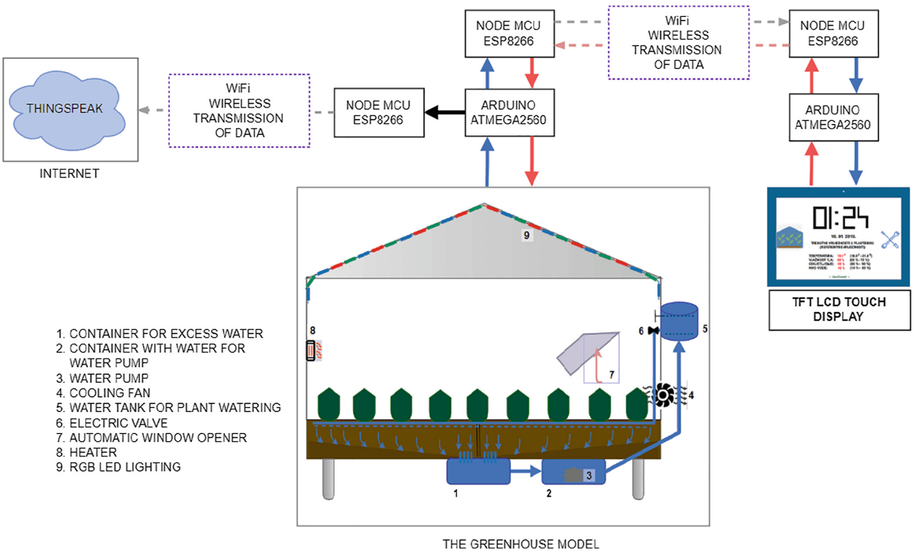

Fig. 2. Functional block diagram of the projected system

In Fig. 2 is shown that the projected system is very complex and consists from several independent subsystems. These subsystems are:

1. Watering subsystem in the greenhouse,
2. Lighting subsystem in the greenhouse,
3. Temperature control subsystem in the greenhouse,
4. Air quality subsystem in the greenhouse,
5. Remote monitoring and control subsystem for greenhouse and
6. IoT subsystem for greenhouse using ThingSpeak cloud.

Each subsystem is described below in this paper.

2.1.1 Watering Subsystem in the Greenhouse Model

In Fig. 3 is shown functional block diagram for the soil moisture and water level measurement. Soil moisture measurement is performed for each part of the greenhouse model separately. In water tank are placed two water level sensors, to detect low and high water level.

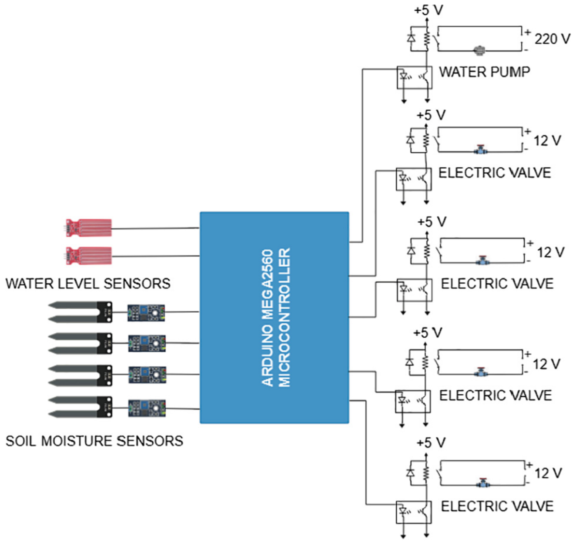

Fig. 3. Functional block diagram for the soil moisture and water level measurement

The watering subsystem in the greenhouse model is realized using water pump to fill the water tank. Water tank is placed at higher altitude than the greenhouse model bottom. Depending on which water lever sensor is active water pump is turn on or off. On the water tank are connected four water pipes. Every water pipe has electric valve to turn on or off the watering. Depending on soil moisture sensors, that are separate for each part for planting, electric valves are turn on or off. If the soil moisture sensor reads value below the desired value which the user had entered, electric valve in that part for planting is turn on. When soil moisture sensor match desired value, electric valve is turn off.

In Fig. 4 is shown functional block diagram for watering subsystem in the greenhouse model.

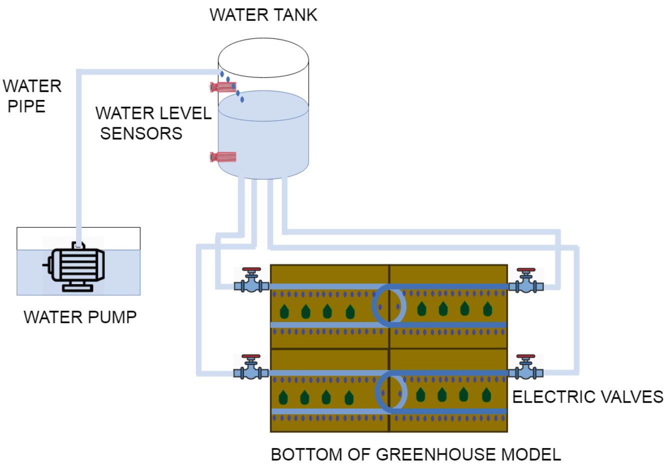

Fig. 4. Functional block diagram for the watering subsystem in the greenhouse model

2.1.2 Lighting Subsystem in the Greenhouse Model

Lighting subsystem in the greenhouse model is realized using the RGB LED strips. For the greenhouse model is used red, blue and green LED color. These colors are used because of their affect to the plant growth. Lighting subsystem in the greenhouse model is realized using photoresistor, Arduino board with ATMega2560 microcontroller and transistor BD137.

Arduino is microcontroller board with Atmel microcontroller ATMega2560 and additional parts needed to operate the microcontroller and external connectors for easy operation and connecting to external elements [10, 11].

The level of light in the greenhouse model depends of the level of the day light. RGB LED light is brighter if day light is darker. In this way plants in the greenhouse gets required light day and night. In Fig. 5 is shown the functional block diagram of the lighting subsystem in the greenhouse model.

Each type of the plants reacts differently depending on the color of the light it absorbs. The source of energy in plants is light. The process of converting light into food is photosynthesis. The color of light that plants absorbs has influence on the amount of energy that plant provides. The reason is that in the light there are different wavelengths. Depending on if wavelengths are short or long, light provides different level of energy.

The light color that provides the most energy is on ultrapurple end of the spectrum of colors. Purple lights have short wavelengths which means higher energy. At the end of the spectrum of colors is red light. Red light has long wavelengths which means

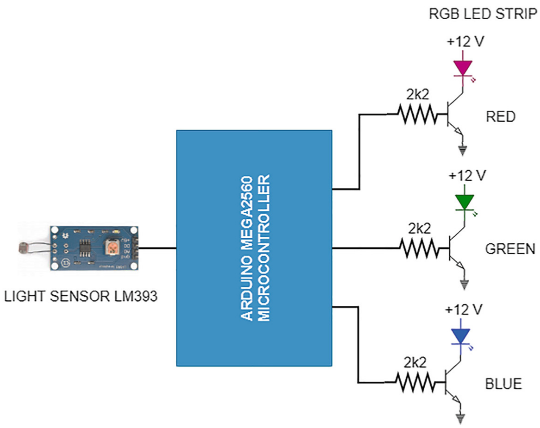

Fig. 5. Functional block diagram of the lighting subsystem in the greenhouse model

lower energy. The green light has a sooting affect on plants because it is the color of their pigment of chlorophyll. Because of that green light do not affect to energy level in plants [11].

Different light colors help plants to achieve different goals. Blue light helps to stimulate vegetative growth and leaves growth. Red light combined with blue light allows early flowering of plants [12]. Knowing that different color of light can affect on how plant grows people can make the most from plants.

Advanced LED technology allows people to control the strength and the color of light. Lighting subsystem is realized in the greenhouse model to encourage fast growth and higher yields.

2.1.3 Temperature Control Subsystem in the Greenhouse Model

Temperature control subsystem in the greenhouse model is used to control temperature in the greenhouse model. Temperature control subsystem consist of: temperature sensor DS18B20, ATMega2560 microcontroller, two optocouplers with relay and heater. In the case when the temperature in the greenhouse model is low the heater is turn on. The heater will be turn on until the temperature grow to desired value. In Fig. 6 is shown temperature control subsystem in the greenhouse model.

Temperature control subsystem also can periodically (with manual user speed) open the window and trigger the fan.

2.1.4 Air Quality Subsystem in the Greenhouse

Air quality subsystem in the greenhouse is designed to track air quality in the greenhouse model. Air quality subsystem consist of: MQ2 gas sensor, ATMega2560 microcontoller, cooling fan and servo motor. In case air quality is lower than the desired air quality cooling fan is turn on for airing. Also, in the greenhouse model is implemented a window for airing which is open by servo motor. The greenhouse model is designed to have a possibility of adding CO_2 to increase the productivity of plants. In Fig. 7 is shown functional block diagram for air quality subsystem.

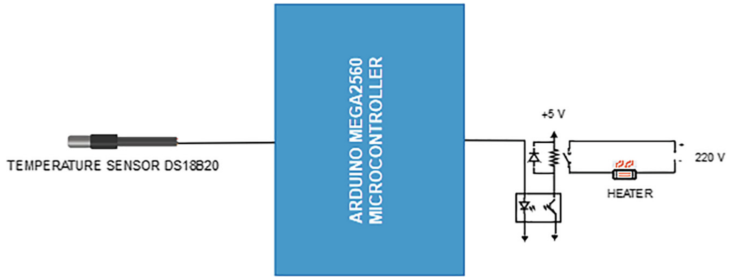

Fig. 6. Functional block diagram for temperature control subsystem

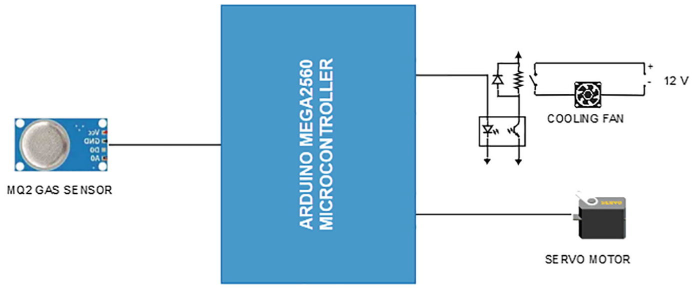

Fig. 7. Functional block diagram for air quality subsystem

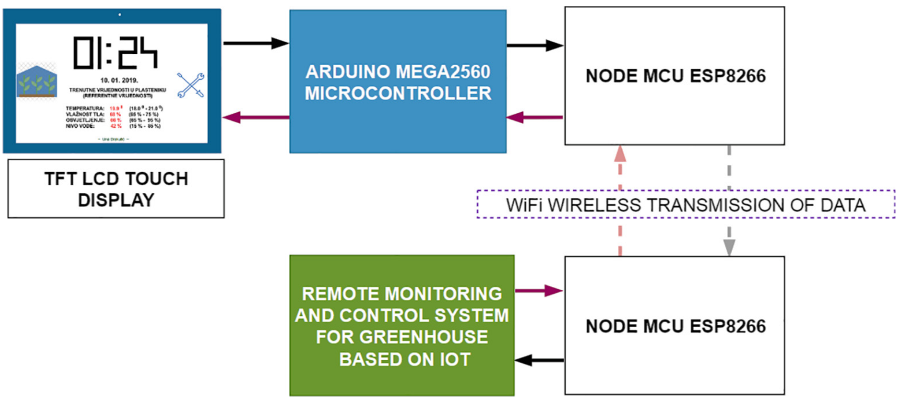

Fig. 8. Functional block diagram for the remote monitoring and control subsystem

2.1.5 Remote Monitoring and Control Subsystem for Greenhouse

Remote monitoring and control subsystem for greenhouse is designed for remote monitoring and control the greenhouse model. Designed subsystem consists of: screentouch displej 3.5 inch and Arduino board with ATMega 2560 microcontroller which is connected to Node MCU esp8266. This part of remote monitoring and control subsystem is on client side. The second part of remote monitoring and control subsystem is on server side. The second part consists of Arduino board with ATMega2560 microcontroller which control the entire designed greenhouse system and regulate all the parameters. In Fig. 8 is shown the functional block diagram for remote monitoring and control subsystem.

In this way, the user can track and set all desired parameters in the greenhouse model. The distance of the user from the greenhouse model can be several hundred meters depending on the current conditions. The main part of this subsystem is remote controller which is realized using 3.5 inch tft lcd touch display. This remote controller must be programmed and for that is used Arduino IDE environment.

Automation of the greenhouse means that all the work that needs to be done in the greenhouse is done by devices. In order to enable automation of the greenhouse, remote controller is made. Remote controller allows user to be away from the greenhouse. The user has access to all relevant data and can set the desired parameters in the greenhouse. Remote controller is shown in Fig. 9.

Fig. 9. Remote monitoring and control device for the greenhouse system

In Fig. 10 we can see that the first window display time and date, desired values (left) and measured values (right). At the bottom of the display are two buttons. The first button is for turn on or off the designed greenhouse system and the second for settings. When button for settings is pressed new window display (see Fig. 10).

In order to protect the user and his greenhouse system, it is implemented a password to proceed other settings. If the entered password is incorrect, the message: ‘Lozinka je netacna!’ (engl. The password is incorrect!) is showing and a new password entry is required. If the entered password is correct, the message: ‘Dobrodosli!’ (engl. Wellcome!) is shown and new window is displayed (see Fig. 11).

In Fig. 11 is shown main menu for settings. The user has tri buttons to choose:

(1) Time and data (in Fig. 11 ‘DATUM I VRIJEME’)
(2) Settings in the greenhouse model (in Fig. 11 ‘PODESAVANJE Staklenika’)
(3) Main window display (in Fig. 11 ‘POCETNA’)

Fig. 10. Window display for password

Fig. 11. Main menu for settings

If the button ‘Time and date’ is pressed, window in Fig. 12 is displayed.

After desired values are entered, all data are saved in EEPROM memory in microcontroller ATMega2560.

In Fig. 13 is shown window display for button ‘Settings in the greenhouse model’.

All entered data, using Wi-Fi wireless network, are sent to Arduino board with ATMega2560 microcontroller in the greenhouse model.

2.2 IoT Subsystem for Greenhouse Using ThingSpeak Cloud

In Fig. 14 is shown IoT subsystem for greenhouse. This system is realized using Node MCU esp8266 module which is connected to Arduino board with ATMega2560 microcontroller in the greenhouse model. Node MCU esp8266 model, using Wi-Fi wireless network, sends received data to the cloud. For this purpose is used ThingSpeak platform.

Fig. 12. Time and date settings

ThingSpeak is the open IoT platform with MATLAB analytics [13].

Fig. 13. Settings in the greenhouse model

In this way is enabled data monitoring in the greenhouse model for a longer period of time as well as overview of all relevant data from any location in the world that has access to the Internet.

Because our system 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 [14].

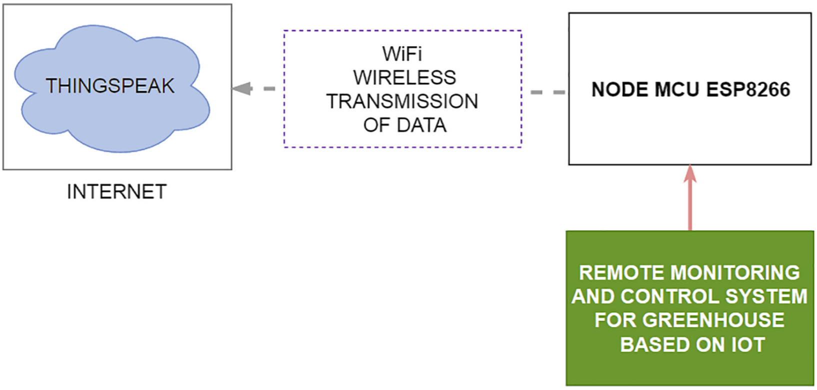

Fig. 14. Functional block diagram for the IoT subsystem

In Fig. 15 is shown appearance of window when user access to cloud to see data.

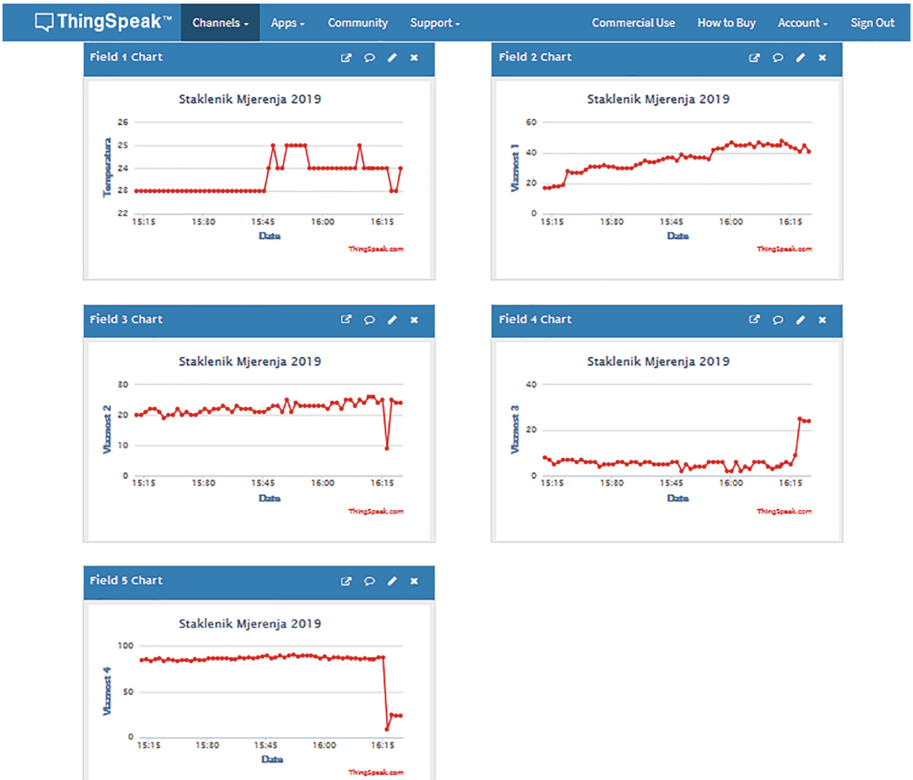

Fig. 15. Appearance of the received data in cloud

3 Final Remote Monitoring and Control System for Greenhouse Using IoT

After connecting all the parts we get the final system which is shown in Fig. 16.

Fig. 16. Appearance of the final designed system

Four types of plants are planted in the greenhouse model (two types of flowers, strawberries and peppers).

All parts of the projected system, except the actuators and sensors, are located below the greenhouse. This is shown in Fig. 17.

3.1 Experimental Analysis of the Designed System

Remote monitoring and control system for greenhouse is automated system. This means that system consists of sensors. Based on the values that sensors read actuators will work. Using remote controller the user sets desired values for different senosors.

For example, if user sets desired temperature in the greenhouse model 21 °C it will maintain that temperature all time. If temperature sensor DS18B20 reads lower temperature the heater in the greenhouse model will turn on until the temperature rise up to desired temperature. If temperature sensor DS18B20 reads higher temperature the cooling fan will turn on and the window will open until the temperature drop down to desired temperature.

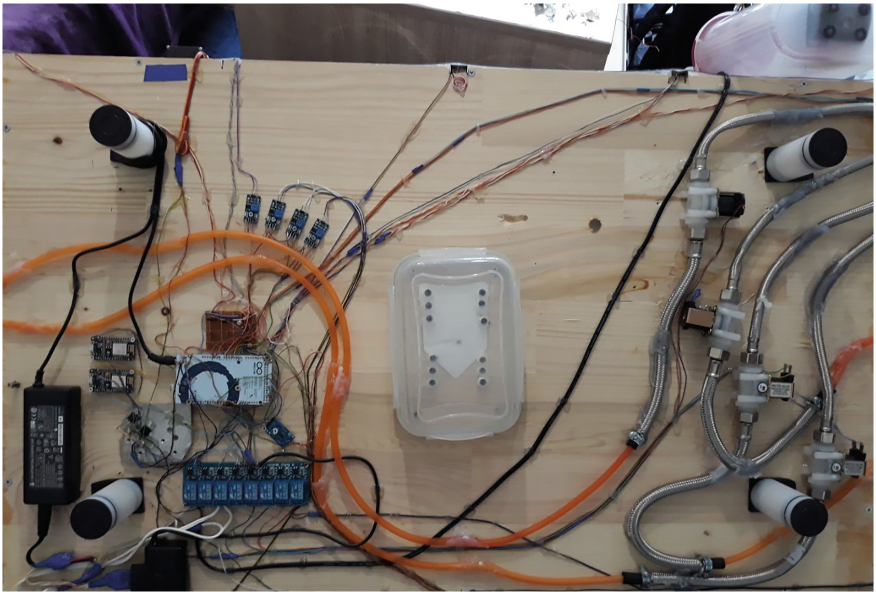

Fig. 17. Appearance of the final designed system from bottom side

Fig. 18. Appearance of the watering part and the airing part in the greenhouse model

When user sets desired soil moisture in the greenhouse model 60% it will maintain that moisture. If soil moisture sensor reads lower moisture then water pump will turn on. Water pump is turn on to fill water tank in which are two water level sensors, for low water level and high water level. When lower level sensor is active water pump is turn on and if higher water level sensor is active water pump is turn off.

In Fig. 18 is shown watering part and the airing part in the greenhouse model.

Lighting subsystem in the greenhouse model is realized so plants always have needed amount of light. If the day light is normal, i.e. bright, RGB LED lights are turn off. When day light is getting lower, RGB LED lights are turning on. If it is dark outside, RGB LED lights are turn on maximum.

In Fig. 19 is shown realization of lighting subsystem in the greenhouse model.

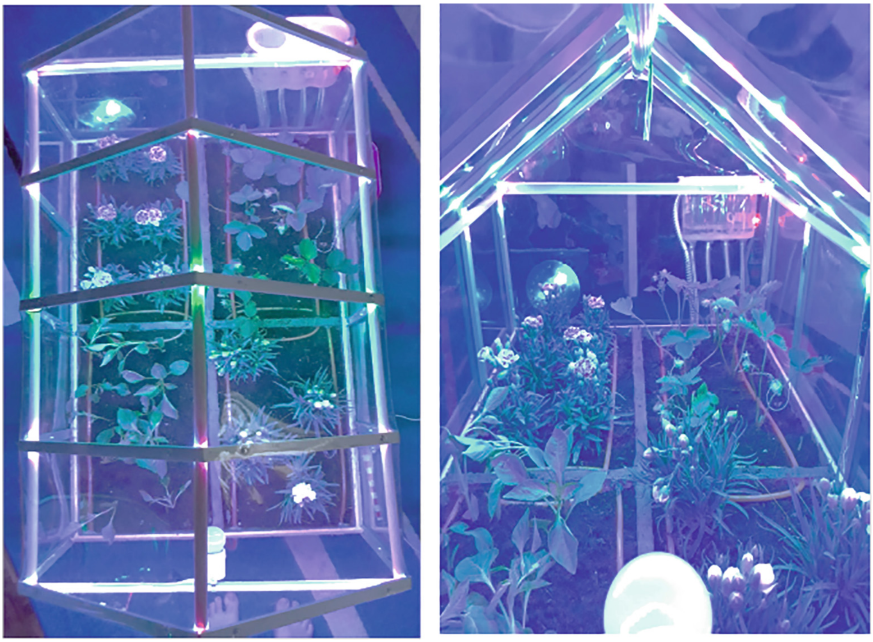

Fig. 19. Appearance of the lighting subsystem in the greenhouse model

4 Conclusion

In this paper is described design and implementation remote monitoring and control system for greenhouse based on IoT. Based on the experimental analysis we can see that the projected system is working properly. We can also conclude that the projected system can, with minimal changes, be applied to the real system. Possible future upgrade of the projected system is adding a CO_2 production system. CO_2 enrichment in greenhouses allows crops to meet there photosynthesis potential. Enriching the air with CO_2 can be done by means of the combustion of natural gas or with liquid CO_2.

On the basis of the obtained results, apply (with minor changes primarily to the actuator) automated greenhouse system for controlling all microclimate conditions in a greenhouse of larger dimensions and apply a knowledge flow on the influence of certain factors on plant growth.

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