Automated Greenhouse Using Arduino Mega

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***Abstract*— Greenhouses are especially important in hot climates. In fact, there are some plants that cannot survive in hot climates; for instance, strawberries, peaches, and pomegranates. In general, Greenhouses are a closed and transparent structure that can be used in home gardens and farms, creating a suitable environment for plants to grow in a relatively cold environment. Furthermore, greenhouses offer some other factors of extreme importance for plants to grow rapidly; to name but a few, cold temperature, suitable humidity, soil moisture, and a cover from harmful winds. A greenhouse is designed in such a way to increase the production of crops and harvest seasons. Moreover, greenhouses are mobile, which makes them easy to transfer from one place to another if need arises. Besides, a greenhouse is not limited to a specific size, but can be adjusted based on the available surface area and number of crops. Unlike traditional greenhouses, the automated greenhouse proposed in this paper will have an automatic irrigation system and a weather controller.**

Keywords-Greenhouse, Design, Construction, Control System, Automated System, Agriculture, Irrigation.

I. INTRODUCTION

The consumption of fruits and vegetables has become of vital importance in most societies. A large number of different kinds of fresh fruits and vegetables are available anytime of the year. However, in a dry climate such as Oman’s, growing fruits and vegetables is a big challenge because of different factors such as the low humidity and the lack of rain. A suitable greenhouse that takes into account the challenges aforementioned is needed to grow fruits or vegetables. A greenhouse is defined as a simply designed house whose ceiling can be made of different materials like, plastic or glass. The selected material depends on the climate condition requirement.

Structure and design of greenhouses affects the crop production. Many developments have appeared related to greenhouse design recently. Those early structured was made to control parameters like temperature and humidity. Nonetheless, these latter did not meet the needed requirements of quality control criteria. Nowadays, the surrounding environment faces many issues and challenges regarding the climate condition. Global warming and weather changes are considered to be the main causes of these latter. Farmers, and the agriculture industry in general, are facing many obstructions regarding the aforementioned issues. Therefore, the automated greenhouse is the best solution to overcome these issues in the agriculture sector. There are several advantages that come with building a structure like that. To mention but a few, its suitability to grow any type of plants, its ability to provide the ideal weather condition and conserve the water, and its ability to decrease the need for technicians since the greenhouse is fully automated. The remaining of this paper is structured as follow. Section II discusses the literature review. Section III, presents the implementation objectives. Section IV, describes the design and the implementation. Section V, present the results. Finally, the conclusion and the future work of the paper are presented.

II. LITRATURE REVIEW

This section will introduce the relevant literature and research projects that have been done before. The concept of the greenhouse is to provide a suitable environment for many different plants. The greenhouse is a method to provide plants such fruits and vegetables all year round with the different weather conditions by control and monitor different parameters such as, humidity and temperature [6].

Waaijenberg [5] conducted a research about the greenhouse design, construction, and the covered materials. Generally, there are many material properties to evaluate the covered material of a greenhouse. For example, the fire behavior, the mechanical strength, the investment costs, the permeability for humidity, and the available dimensions. Another parameter which will be affected by a covering material is the light transition. Light transition relies on the covered material of the greenhouse.

The concept of growing different types of plants in a monitored and controlled environment came from "Rome under the reign of Emperor Tiberius"[13]. It was found that similar papers only focus on the temperature, the humidity, and the irrigation system. For a plant to grow with a good quality, it needs enough space to develop its roots, an appropriate amount of water, adequate lighting, oxygen, a suitable temperature, and mineral. Kumar et al [8] suggested the usage of microcontrollers for controlling greenhouses. The aim of this project was to enhance plants’ growth by providing a suitable environment and a controlled irrigation system to offer a sufficient amount of water. The sensors utilized in this project are: a soil moisture sensor, a temperature sensor, and a humidity sensor. Each and every recorded value is presented on a Liquid Cristal Display (LCD) that enables the farmers to easily maintain the environmental parameters environment of the greenhouse.

On the other hand, Shaker et al. [1] built a greenhouse project to control the climate and the irrigation system inside the greenhouse by using Wireless Sensor Network (WSN). The structure of this project aimed at providing environment where the climate can be fully controlled in order to protect the plants from any external weather condition.

III. Implementation objectives

The main purpose of this automated greenhouse is to design and implement a greenhouse for plants that can be automatically controlled and monitored by using a microcontroller.

The detailed objectives of this project are as follow:

- Optimizing the usage of Energy by controlling the energy consumption.
- Minimizing the usage of water by controlling the irrigation system, and providing the needed amount of water.
- Designing and constructing the structure of the greenhouse by selecting efficient and appropriate materials.
- Designing and implementing an Automated Irrigation System.
- Maintaining the climate factors inside the greenhouse's environment.

The greenhouse will be fully automated system so there is no need for human interventions. In addition, it will be open source which, make it unique and different from the others projects.

IV. Design and implementation

To achieve the project objectives, using Arduino as a microcontroller seems to be the best choice since it supports open hardware and software systems. In addition, it has a very low cost and it is available on the local market. The choice of materials was as follows. A Field Control System: this step depends on the working of different sensors used in this project which are the soil moisture, the temperature and the humidity, the lighting, the water flow, the gas, a SIM card and electric current. The testing and programming for every sensor was done separately. The first sensor used is the temperature and humidity sensor and then we added the other different sensors which are the soil moisture, PH level, light, SIM card, MQ-7, flow meter, and current. However, different actuators such, pump, light, and fan are installed to. The second step is the project preparation. For the purpose of building the structure of this project, plastic and aluminum were used.

A. Design Process

Selecting of structural material of the greenhouse depends on the cost and availability, technical characteristics, and local climate. Furthermore, the selection of these materials is based on the requirements of design strength, physical properties, life expectancy, and cost of construction materials

a)Frame:

The frames for the greenhouse are essential because without good solid frames, any greenhouse would not stand properly. There are a variety of materials that may be used for the frames of the greenhouse. Each material has advantages and disadvantages. Selecting the suitable choice of frames will have a good impact on the greenhouse structure.

Aluminum is the selected material for the greenhouse frame. It is considered as a low maintenance material, and can be used for a long time. This material cannot break or rust easily. It supports the members which are made from the heaviest pieces. Moreover, it supplies good rigid for the plastics, and it can be painted in any color. It has several advantages such as its lightness and robustness. Also, it is suitable in any environmental condition and will not face any corrosion, unlike iron.

b)Covered material:

Covering material of the greenhouse is also an essential part that affects the productivity of the crops and the structure performance of the greenhouse. It also affects the amount of light needed for growing plants. Several characteristics should be considered in choosing the most suitable covering material such as, weight, amount of transmitted light, cost, amount of transmitted energy, and the ease of maintenance.

Polycarbonate plastic is the selected material for covering the greenhouse. It has better insulation and a natural light filter which conserves the plants from harmful radiations. This plastic consists of UV radiations, which is used in outdoor areas. UV radiations help the plastic to prevent the deterioration and yellowing from sun radiation. It is available anywhere there is strong wind and other mechanical stress. It is a fully transparent material. The transparent corrugated plastic provides strength and a protection from high temperature. Also, it consists of clear bubble insulation which provides a protection from cold weather.

The greenhouse profile is generally of lean type design, with 60 cm width, 80cm length and 80 height. The last step was to assemble all parts together to finalize the project construction besides the last step in the coding process was to gather all codes in one single program and run it in a large-scale project to make sure that everything is working perfectly.

B. System block diagram

Figure 1 shows the system block diagram. The greenhouse environment in this project is controlled and monitored by the microcontroller Arduino Mega. This latter controls and monitors the plants within this greenhouse, which is lettuce in this case, by utilizing the sensors, mainly the humidity, temperature, and current sensors. The fan and water pumps are the actuators used in this project. In addition, the Arduino software or "Arduino Integrated Development Environment" was used to develop the different codes that are used in this project the language of this software based on C++ language. The first sensor utilized is the humidity and temperature sensor. This sensor is responsible for sending the value of the temperature and the humidity inside the greenhouse. If

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a temperature higher than 26 degrees Celsius is recorded, fan will be activating it to regulate it. On the other hand, if a temperature lower than 26 C is recorded, the fan will be deactivated and the lamp will be turned on to work as "sun" in order to regulate the temperature. The same goes for the humidity, the humidity will be sensed during the system operation. If the humidity level exceeds 34%, the fan will be turned on, and if it goes below 31%, the lamp will be activated. The second sensor is the soil moisture sensor this sensor detects the soil moisture percentage. If the detected moisture percentage is less than 35%, it is concluded that the soil is very dry and the water pump machine will be turned on to irrigate the plants inside the greenhouse. However, if the sensor detects a soil moisture percentage higher than 35 %, it is concluded that the soil is wet, and there is no need for irrigation. Regarding the light sensor (LDR), it will work if it senses that the value of the LDR is lower than threshold. Then, the light will turn on, and vice versa. following to that, the PH sensor will work if the PH inside the main tank become less than 8, then the second water pump will operated to stabilize the PH value. In addition, the carbon monoxide sensor will detect the amount of CO inside the greenhouse. If the CO concentration is more than 120 ppm, the SIM sensor will be activated and a message will be sent to the greenhouse' owners. Finally, the water flow detector is installed to sense the water flow rate record the water consumption in liters.

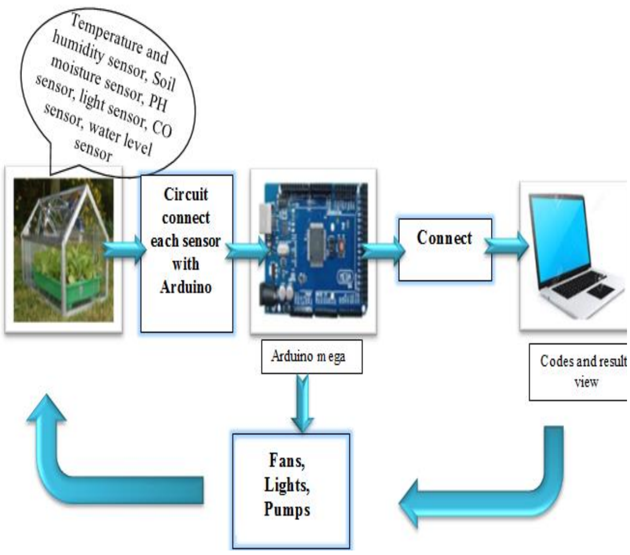

Figure 1. System block diagram

C. *Automated greenhouse flowchart*

The flowchart in Figure 2 presents the different sensors and how each of them works. The flowchart represents the used sensors and how they operate. The environment of the lettuce crop is monitored by the Arduino Mega microcontroller that controls the needed sensors for the plant and offers the suitable environment. These sensors are PH, soil moisture, light, temperature, and humidity. Moreover, there are some actuators which are installed in the greenhouse in order to maintain the suitable environment. These actuators are fan, lamps and pumps. Firstly, the humidity and temperature sensors are used to measure the temperature and humidity value. If the temperature is more than 26 degree, then the fan will work to reduce it and if it is less than 26 then the lamps will work to heat the greenhouse. The second sensor provides the suitable value of the PH value. If the PH value is more than 8 in the main tank, then the pump will work to provide more water from the other tank until it reaches 8. Thirdly, the light sensor detects the brightness inside the greenhouse. If the LDR value is less than threshold then the lamps will work. Furthermore, Furthermore, soil moisture sensor detects the amount of water in the soil. If the soil moisture is less than 35%, then the pump will work to provide the needed water for lettuce. Then, if the carbon monoxide sensor records that the value of CO more than 120ppm, a message will be sent to the owner of the greenhouse. Finally, both values of the current sensors will be represented on the LCD during the fan and the pump operation.

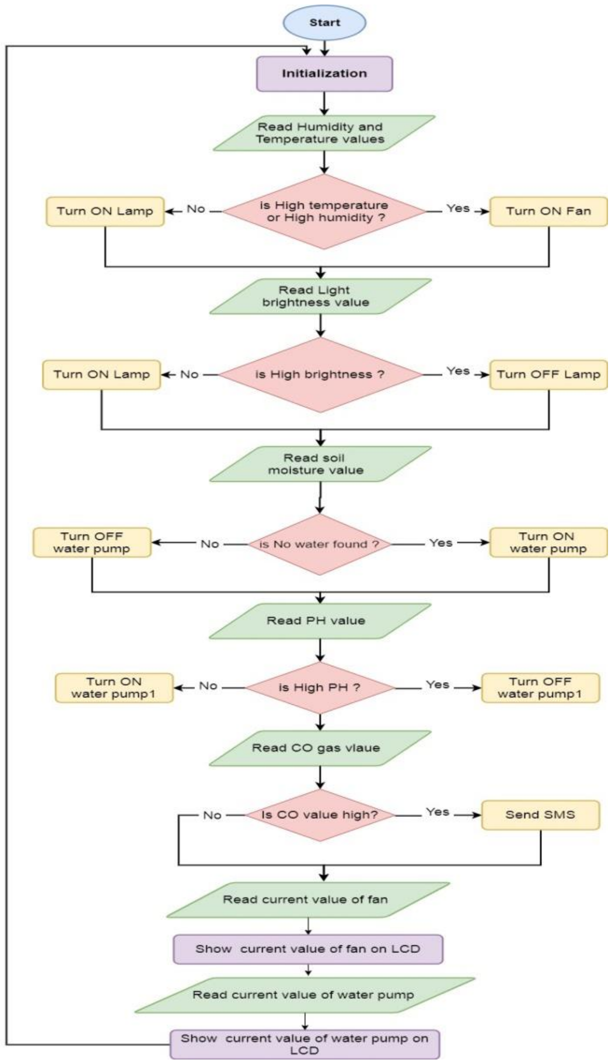

Figure 2. Flow chart of the project

V. RESULTS AND DISCUSSION

Selecting the materials:

1. Aluminium: it is very light in weight which is needed to build the greenhouse structure to handle it

everywhere, and to protect it from the climate conditions such as strong wind.

2. Polycarbonate plastic: it is easy to fit and handle. Replacing polycarbonate plastic sheets from the greenhouse is much easier, but to be more careful when installing any material in polycarbonate plastic because it gets damaged quickly.
3. Light bulb: incandescent lights are reliable and have a full brightness as soon as the key switches on. The quantity of lose heat is very high which increases the temperature inside the greenhouse and affects the growth of the plants.
4. Fan: it is one of the high performance cooling products.

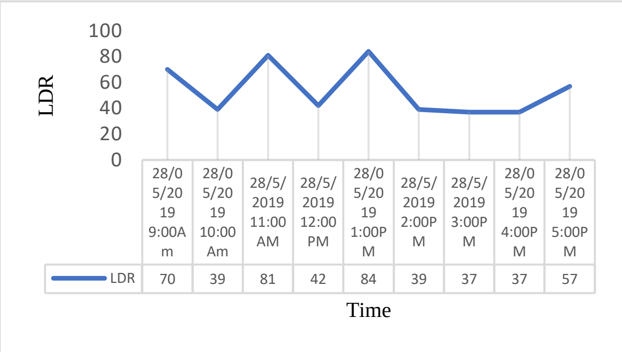

Figure 3. LDR Sensor

The line graph in Figure 3 illustrates the values of the LDR sensor that detect the brightness inside the greenhouse from 9:00 AM to 5:00 PM. It can be clearly seen that the LDR values are fluctuating during that period. Moving on to the details, the highest values were recorded at 9, 11 and 1:00PM, while the lowest values were recorded at 3:00 and 4:00PM.These changes happened because the LDR sensor detects the brightness from the lights which are installed inside the location of greenhouse.

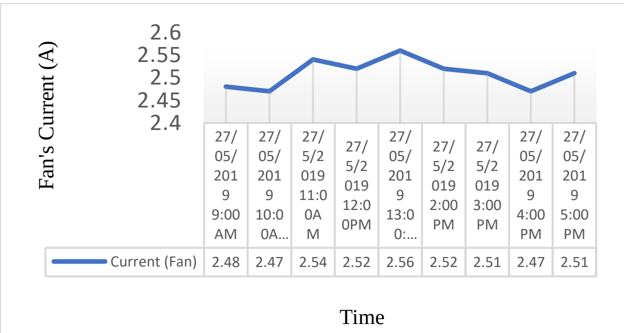

Figure 4. Fan's current

The line graph from Figure 4 presents the values of current sensor that monitors the fan consumption with the time from 9:00 AM to 5:00 PM. The overall trend shows a fluctuation in the fan's current values. Back to the details, the highest value was recorded at 1:00 PM, whereas the lowest value was recorded at 4:00 PM. These fluctuations happened because the fan was switched on and off during the period due to a temperature change.

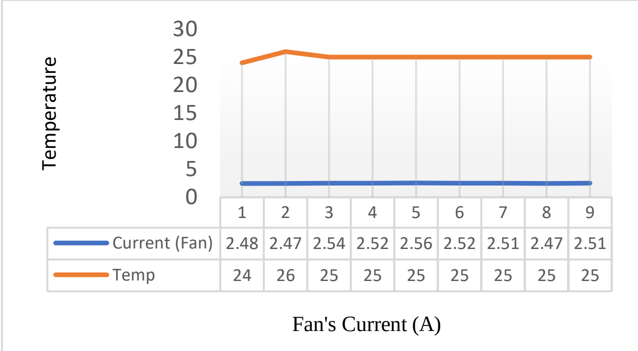

Figure 5. Fan's Current & Temperature

Figure 5 presents the comparison between the fan's current and temperature from 9:00 AM to 5:00 PM. The y-axis presents the temperature values while the x-axis shows the fan's current in Ampere. It can be clearly observed that both lines are constant during the period.

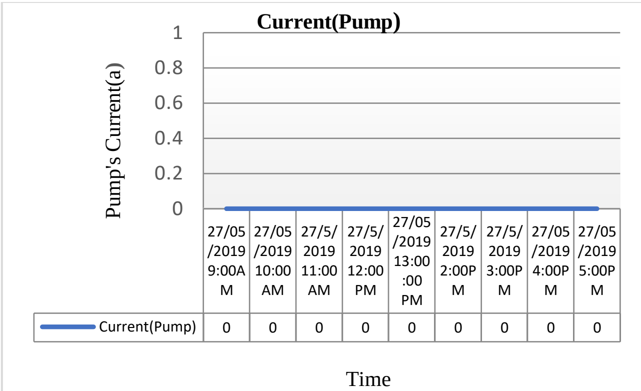

Figure 6. Pump's (OFF) Current

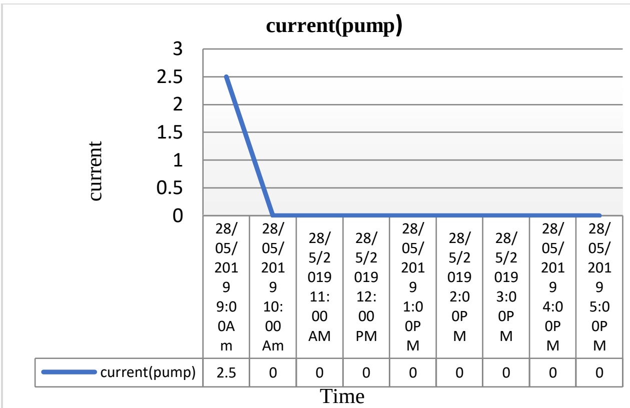

Figure 7. Pump's (ON) Current during Irrigation

The two-line graph in Figures 6 and 7 shows the current sensor for the pump with the time from 9:00AM to 5:00 PM. In the first graph, it can be observed that the pump's current values are almost zero because the pump was switched off. Whereas in the second graph, the value for the pump's current was 2.5 Ampere because the pump was switched on. The pump was switched on because the

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soil was dried. In the remaining time the values are almost zero because the soil had enough water.

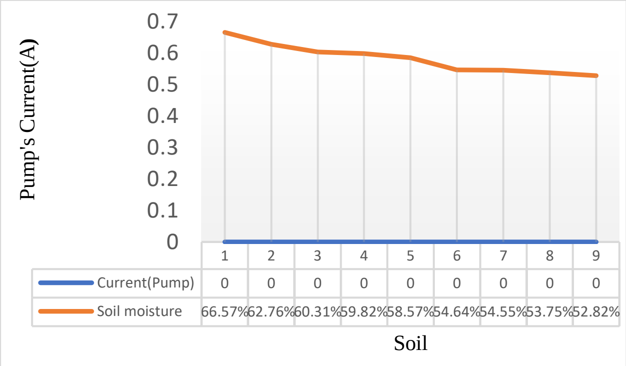

Figure 8. Pump's (OFF) Current & Soil Moisture

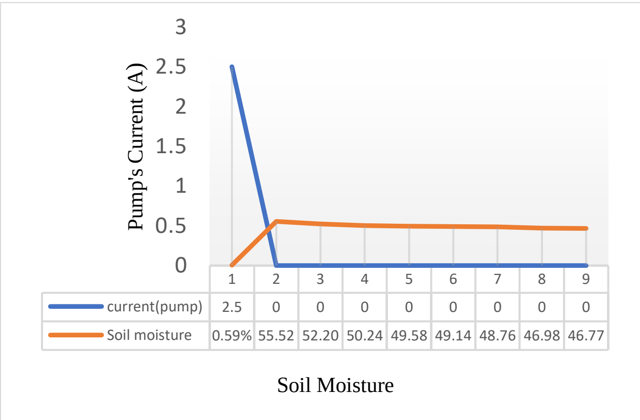

Figure 9. Pump's (ON) Current & Soil Moisture

The two graphs in Figures 8 and 9 show the comparison between the pump's current and soil moisture. The x-axis represents the pump's current while the y-axis represents the percentage of soil moisture. In the first graph, the values of soil moisture were decreased gradually but the pump's current values were almost zero during the period. Whereas in the second graph, the value for the pump's current was 2.5 ampere at the first period. The soil moisture value was recorded in that time was 0.59%. In this situation, the pump was switched on to irrigate the plants. In the remaining time, the pump's current values are almost zero.

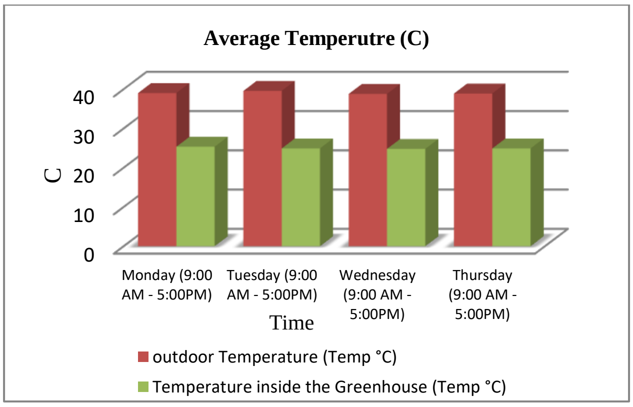

Figure 10. Temperature Average

For the humidity and temperature sensor, it has been noticed that if the value of the temperature that appears in the LCD Screen becomes more than the fixed temperature number in the system, the sensor shows response to that and the Fan will be switched on to decrease the value of the temperature. The chart in Figure 10 shows the average temperature in Celsius for outside and inside the greenhouse. The results were recorded for 4 days (Monday, Tuesday, Wednesday, Thursday), each day from 9:00AM to 5:00PM. Looking to the graph, the temperature inside the greenhouse was recorded with a constant value 25 for whole the days. On the other hand, the outside temperature recorded an average value between 38 and 39 for the same period.

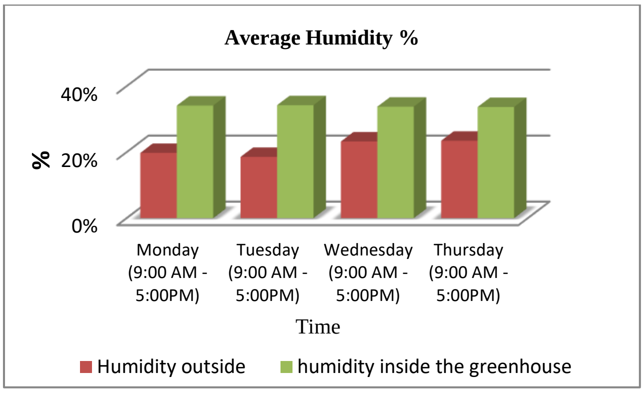

Figure 11. Average Humidity

Regarding the humidity controls, if the percentage of humidity is either less or more than the fixed point in the system which is 35%, the sensor will detect that and the fan will be operated in order to decrease the value of the humidity inside the greenhouse. The next chart in Figure 11 shows the average percentage of the humidity for a period of four days beginning with 27/5/2019 until 30/5/2019 for each day from 9:00 AM to 5:00 PM. The humidity in the greenhouse environment was compared with the outside humidity. In general, it is clear from the graph that the humidity inside the greenhouse was constant during that time for all the mentioned days, which means that the control system works efficiently. On the other hand, the outside humidity was varying with a range of 19% to 23% during the same time of the change in the other condition outside.

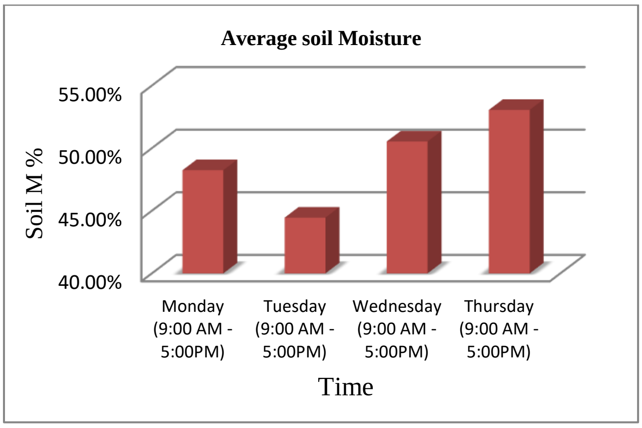

Figure 12. Soil Moisture Average

In this test, it has been noticed that when the percentage of the soil moisture becomes lower than the limited value (35%), it was detected by the sensor and a signal was sent to operate the pump to irrigate the plants in the controlled greenhouse. Nevertheless, if the soil moisture sensor sense that the value of the moisture exceeds 35%, a signal is sent to the system to stop the irrigation process as the plants have enough water. Moreover, Figure 12 shows the average percentage of the soil moisture for a period of 4 days between 9:00 AM and 5:00 PM daily. Looking into the graph, it can be recognized that the soil moisture average has declined on Tuesday due to the results that was recorded during the day has the lowest value between the four days. However, the percentage of the soil moisture increased gradually on Wednesday and Thursday.

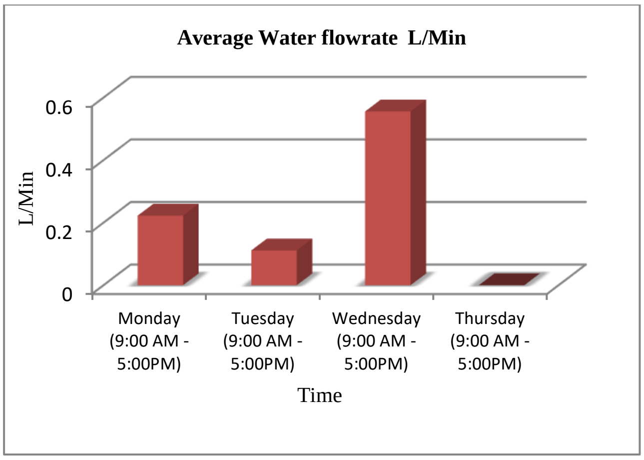

Figure 13. Water Flow Average

In Figure 13, the water flow sensor works to detect the water flow that enters the greenhouse. When the soil becomes dry, the sensor of soil moisture sends a signal to operate the pump. During that time, the water flow sensor will record the water flow. The chart above in Figure 13 illustrates the average water flow amount during the aforementioned period. It is clear from the graph that the water flow rate recorded the lowest amount on Wednesday with a value of 0.557 L/Min. Nonetheless, it has the lowest value on Thursday because the plants were not irrigated during the system operation. On the fourth day, the data of the water flow was 0 L/Min for the whole period because the soil has enough water and there is no need to irrigate the plants.

Figure 14 compares the soil moisture to the water flow rate for the first day. What is noticeable is that there is a direct relationship between the water flow and the soil moisture. When the water pump works to irrigate the plants, the amount of water increased sharply to reach its peak. During that same time, the soil wetness percentage increased and the same was noticed during the whole days.

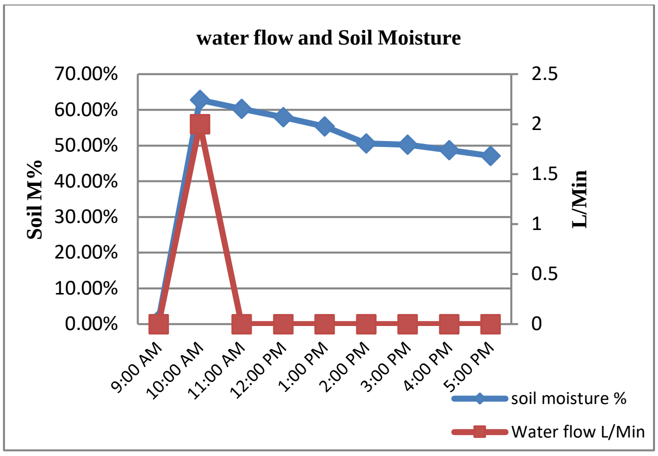

Figure 14. Water Flow & Soil Moisture

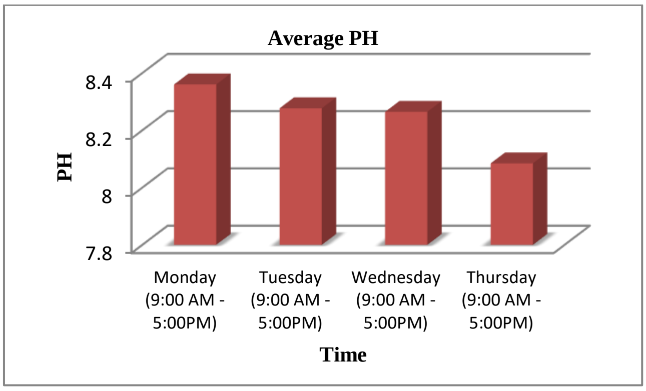

Figure 15. PH Average

The PH sensor works to sense the PH level into the main tank which is used for the irrigation system. When the value of the PH becomes more than threshold, the sensor detects that and the second pump is operated to push water into the main container to decrease the PH level. Figure 15 demonstrates the daily PH level. Overall, the PH level is at its highest on Monday because the water was not used before. In contrast, the lowest value was in Thursday with a value of 8.08. In general, the water that used in the tank considered basic.

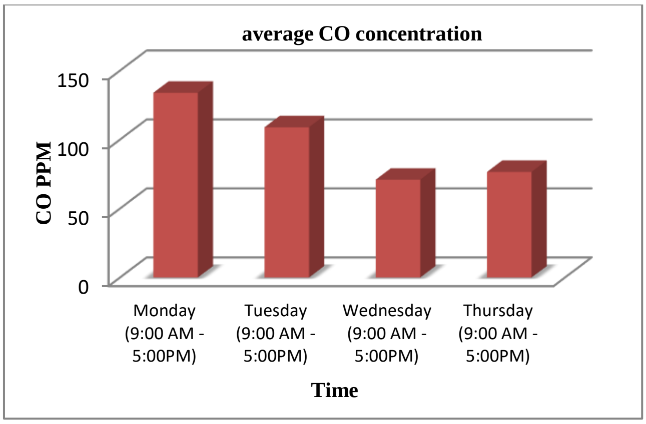

Figure 16. CO Average

The MQ-7 sensor is used. This sensor detects that the value of the gas (CO). If the said value is more than the threshold, a message will be sent to the owner in order to quickly check the greenhouse. The above chart in Figure 16 demonstrates the average value of the gas (CO) in PPM for a period of 4 days, each day between 9:00 AM to 5:00 PM. What is noticeable on Monday the CO concentration recorded as the highest value its reach 133 ppm. On the other hand, the lowest value was recorded on Wednesday with a value of 70 ppm.

VI. CONCLUSION AND FUTURE WORK

The main purpose of this research project is to construct, design, and implement a fully automated greenhouse with an efficient design to provide a suitable environment for growing plants using an Arduino microcontroller. The greenhouse is constructed using Aluminum as a supported frame and polycarbonate plastic as a cover material. The choice these materials is based on the previous studies about constructing a greenhouse. The selected design is lean-to type greenhouse that is mobile and easily transferrable. We achieved successful results with this project. In fact, the sensors used showed very promising response with a success percentage reached to 90% in detecting and sending signals to Arduino, to control the climate parameters and the irrigation system. By having this efficient system inside greenhouse, the lettuce productivity increased, water and energy consumption were optimized, and manpower decreased.

Regarding the future works, intelligence with data processing and prediction will be carried out to improve the result. In addition, a possible extension of this project would involve creating a knowledge management system, where several cases are going to be fed into the system for future predictions and recommendation purposes.

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