UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical Technology and Engineering

DEVELOPMENT OF AUTOMATED GREENHOUSE SYSTEM FOR STRAWBERRY PLANTS POWERED BY SOLAR ENERGY

MUHAMMAD HASAN BIN MAT SHAFIE

Bachelor of Electrical Engineering Technology with Honours

2023

DEVELOPMENT OF AUTOMATED GREENHOUSE SYSTEM FOR STRAWBERRY PLANTS POWERED BY SOLAR ENERGY

MUHAMMAD HASAN BIN MAT SHAFIE

A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering Technology with Honours

Faculty of Electrical Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI KEJUTERAAN ELEKTRIK DAN ELEKTRONIK

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : Development of Automated Greenhouse System For Plants Powered by Solar Energy.

Sesi Pengajian : 23/24

Saya Muhammad Hasan Bin Mat Shafie mengaku membenarkan laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (✓):

☐ **SULIT*** (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

☐ **TERHAD*** (Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☑ **TIDAK TERHAD**

Disahkan oleh:

(TANDATANGAN PENULIS)

Alamat Tetap: 96, KG SURAU PANJANG,
21070 KUALA TERENGGANU,
TERENGGANU

(COP DAN TANDATANGAN PENYELIA)

ARMAN HADI BIN AZAHAR
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan Elektrik
Fakulti Teknologi dan Kejuruteraan Elektrik
Universiti Teknikal Malaysia Melaka

Tarikh: 27/01/2024

Tarikh: 16/02/2024

*CATATAN: Jika laporan ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh laporan ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I declare that this project report entitled "Development of Automated Greenhouse System For Plants Powered by Solar Energy." is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Student Name : MUHAMMAD HASAN BIN MAT SHAFIE

Date : 27/01/2024

APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology with Honours.

Signature :

Supervisor Name : ARMAN HADI BIN AZAHAR

Date : 16/02/2024

Signature :

Co-Supervisor Name (if any) : DR. NOR HAFIZAH BINTI HUSSIN

Date : 19/2/2024

DEDICATION

This report is dedicated to my beloved mother and father. I pay to Allah Almighty for the health and forgiveness of our parent who have given us a lot but claimed nothing.

ABSTRACT

The purpose of this project is to develop automated greenhouse system. In order to help farmers in producing fruits that require a specialised climate that is different from the surrounding climate in which they are currently living, it is imperative to build a system that maintains a regulated environment viable for growing strawberry plants. Also, this project compares greenhouse cooling technologies with modern, renewable energy-based ones in order to employ clean energy, reduce the likelihood of environmental impact, and consume less energy, like solar energy. The main problem with greenhouses is horticulture based on optimal management of the greenhouse environment to meet economic and environmental requirements. Extreme heat and humidity needs to be controlled and watering is necessary to provide water. The solution to these problems is the design of automatic greenhouse. The parameters controlled in the greenhouse are the watering system, humidity and temperature sensors. The system is automatic, consumers do not have to be there to physically apply water to the plants, control temperature and humidity in a greenhouse. This system can avoid excessive presence of water in crops and avoid wasting water. These projects have improved the watering system from manual to automated, facilitating remote monitoring to automatically collect greenhouse conditions and data for research purposes. "Development of Automated Greenhouse System for Strawberry Plants Powered by Solar Energy" as the main brain to control all parameters of the greenhouse environment.

ABSTRAK

Tujuan projek ini adalah untuk membangunkan sistem rumah hijau automatik. Dalam usaha untuk membantu petani dalam menghasilkan buah-buahan yang memerlukan iklim khusus yang berbeza daripada iklim sekitar di mana mereka kini hidup, ia adalah penting untuk membina satu sistem yang mengekalkan persekitaran yang dikawal selia berdaya maju untuk tumbuh-tumbuhan strawberi. Juga, projek ini membandingkan teknologi penyejukan rumah hijau dengan yang moden, berasaskan tenaga boleh diperbaharui untuk menggunakan tenaga bersih, mengurangkan kemungkinan kesan alam sekitar, dan menggunakan lebih sedikit tenaga, seperti tenaga suria. Masalah utama rumah hijau adalah hortikultur berdasarkan pengurusan persekitaran rumah hijau yang optimum untuk memenuhi keperluan ekonomi dan persekitaran. Haba dan kelembapan yang melampau perlu dikawal dan penyiraman diperlukan untuk menyediakan air. Penyelesaian kepada masalah ini adalah reka bentuk rumah hijau automatik. Parameter yang dikawal di rumah hijau adalah sistem penyiraman, kelembapan dan sensor suhu. Sistem ini automatik, pengguna tidak perlu berada di sana untuk menggunakan air secara fizikal ke tanaman, mengawal suhu dan kelembapan di rumah hijau. Sistem ini dapat mengelakkan kehadiran air yang berlebihan dalam tanaman dan mengelakkan pembaziran air. Projek-projek ini telah meningkatkan sistem penyiraman dari manual ke Automatik, memudahkan pemantauan jarak jauh untuk mengumpulkan keadaan dan data rumah hijau secara automatik untuk tujuan penyelidikan. "Pembangunan sistem rumah hijau automatik untuk tanaman strawberi yang dikuasakan oleh tenaga suria" sebagai otak utama untuk mengawal semua parameter persekitaran rumah hijau..

ACKNOWLEDGEMENTS

First and foremost, I express our gratitude to our creator, The Almighty Allah for giving us a mental and physical power to complete this final year project "Development of Automated Greenhouse System for Strawberry Plants Powered by Solar Energy" as partial fulfilment For Bachelor of Electrical Engineering Technology (Industrial Power) With Honors.

In preparing this report, I also gratified to our supervisor that is Encik Arman Hadi Bin Azahar, Senior lecturer of the Faculty of Electrical and Electronics Engineering Technology of Universiti Teknikal Malaysia Melaka whom is involved directly from the beginning of our final year project till the completion. I feel very obliged because she never gives up in guiding us by giving advises and sharing her opinion, ideas and commitment to us until the project is done. Without her support and interest, this thesis will not have been finished the same as represented here. Thank you for giving help and guidance no matter in what aspect but I really appreciate for their cooperation in doing this project and thesis completely.

Most importantly, my beloved parents and family, who have made great contributions to help me reach this point in my life. This would not have been possible without the infinite love and support they have given me all the time.

Finally, I would like to thank the University of Technical Malaysia Melaka (UTeM) for giving me the opportunity to experience real life. I see this opportunity as an important milestone in the development of my career.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

V	-	Voltage
℃	-	Celsius
%	-	Percent
lux	-	Illuminance
DC	-	Direct Current
AC	-	Alternating Current

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

This project is based on Malaysia's agricultural industry. The development of greenhouse is needed in order to boost the strawberry production and to close the gap between the demand and supply needed. Besides, this project also is able to reduce the yield of imported strawberries by closely monitoring strawberry plants that will be grown in greenhouses in our own country.

The tropical climate of Malaysia, characterized by high temperatures, humidity, and abundant sunlight, makes greenhouse cultivation an effective method to control and optimize growing conditions. The greenhouse system has been examined in greenhouses of ShengFangYuan Test Station in Beijing, China; the result shows that the system can instruct greenhouse irrigation efficiently, increase yield 18%, and save water 28% [1].

Figure 1.1 Example of Strawberry Greenhouse

A greenhouse is a building that's usually made of glass or transparent materials, designed to create a controlled environment for the cultivation of plants. It provides a sheltered space where plants can grow in the best conditions. Experimental research was done on environmental factors like relative humidity, solar radiation, and ambient temperature. According to the study's findings, the biggest temperature difference between inside and outside air during the evaluation period was 16.4 °C. When compared to ambient solar radiation, the maximum reduction in solar radiation through a transparent vinyl sheet in the greenhouse was roughly 30% [2].

The controlled environment of greenhouses enables growers in Malaysia to produce high-quality crops with consistent characteristics. By managing factors like temperature, humidity, light exposure, and nutrient availability, farmers can enhance the flavor, color, and overall appearance of their produce. This can result in better market value and increased consumer satisfaction.

Moreover, one of the factors that affect plant growth in a greenhouse is the amount of water in the soil or soil moisture [3]. Plants in greenhouses may not be able to grow well if there is too much or too little water present, so a system that can maintain the soil's moisture level according to the needs of the plant automatically is required. By measuring the greenhouse soil parameters and strawberry soil moisture data to determine the upper and lower limits of irrigation and set buried position of moisture sensors [4].

An automated greenhouse system powered by solar energy combines the benefits of greenhouse cultivation with sustainable energy sources. Solar panels are integrated into the system to produce electricity, which is then utilized to power different greenhouse components and automation systems. A new-type of Sliding cover Energy-saving solar Greenhouse (SEG) has been developed, the key structural issues with conventional solar greenhouses that it is addressing are the energy capture and balancing features [5].

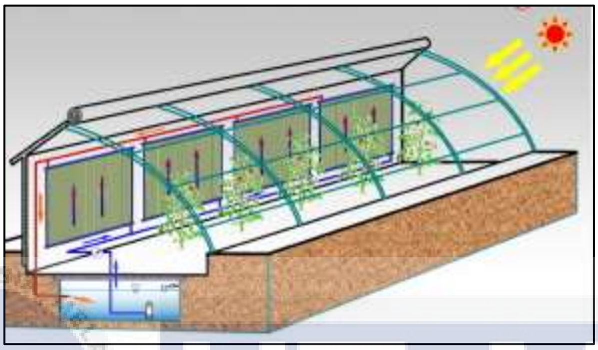


Figure 1.2 Sliding Cover Solar Greenhouse

Figure 1.3 Innovative In Solar Energy Greenhouse PV Solar (YUMPU eBook, 2011)

In addition, the automated greenhouse systems and data logging is essential. Data logging is used to collect and analyze data to improve crop / plantation production rates. In addition, you can protect your crops from the weather by automatically checking the greenhouse environment. Heating requirements were estimated to achieve optimal cultivation conditions in the future [2].

1.2 Problem Statement

There are many problems that occur currently in agriculture industries. Unexpected weather or condition changes, labor shortages and dry soil are some of the reasons that can cause plants to grow. The climate in Malaysia is inconsistent due to the effects of global warming [6]. Therefore, plant growth is affected by weather conditions. In order to increase crops, plants or crops need favorable conditions to grow well.

Additionally, the lack of real-time data analysis and monitoring mechanisms hinders the timely detection of issues related to plant health and sensor functionality. There is also a need to address the environmental impact of conventional greenhouse practices, where resource wastage is not adequately minimized, presenting an opportunity for a more sustainable approach.

Furthermore, favorable conditions for crops such as air humidity, temperature, heat index, sunlight illumination and soil moisture are not recorded automatically. This is the reason why future improvement for the crop's growth cannot be execute for the research and development of the plants cannot be monitored thoroughly. Without recorded data, there is a lack of information to analyze, and no investigation for improvement is possible.

1.3 Project Objective

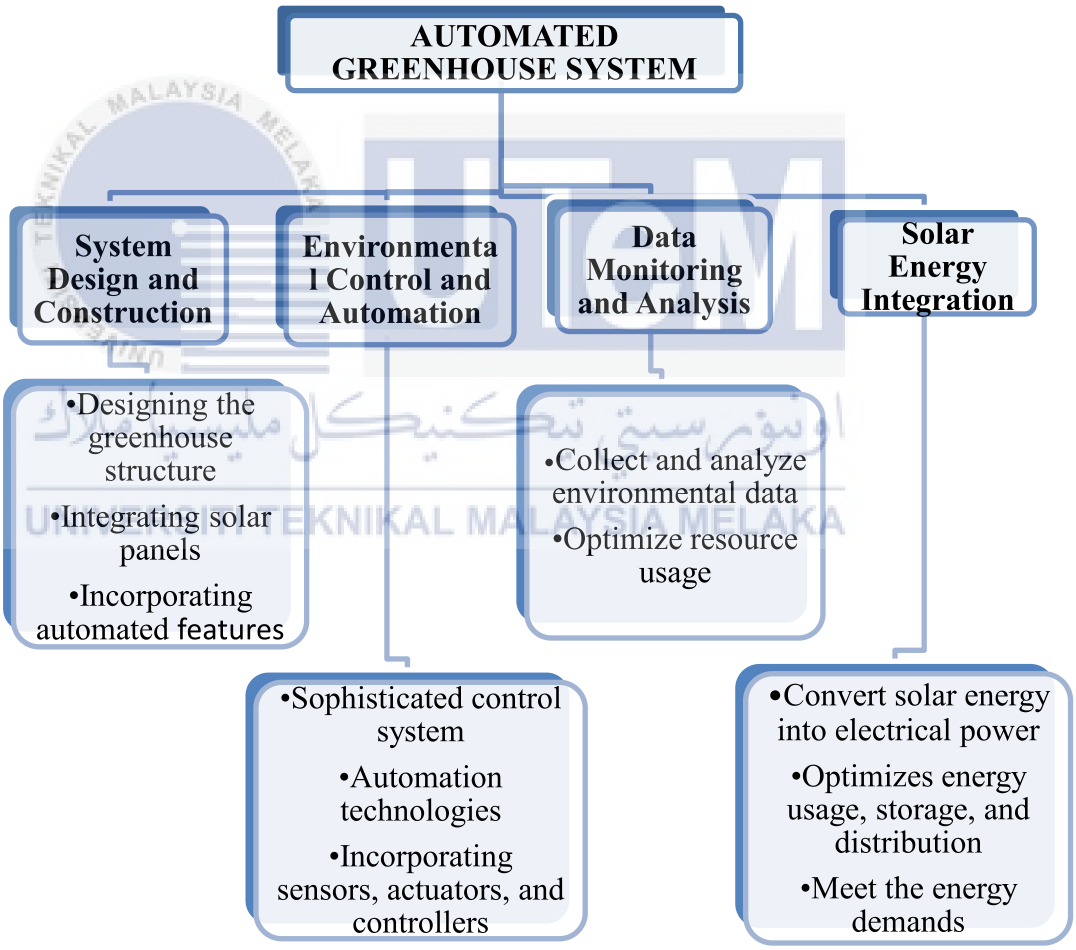
The main aim of this project is to propose a systematic and effective methodology. Specifically, the objectives are as follows:

a) To develop a greenhouse that can control the plant environment within the boundaries of the greenhouse.

b) To analyze and monitoring the collected data in order to determine the health of the plant and functionality of the sensors.

c) To minimize waste and ensure the sustainable use of resources.

1.4 Scope of Project



1.5 Chapter Summary

As a summary for this chapter, it can be concluding that the objectives of this project are to develop a controlled environment for the plant. Therefore, it will overcome the dependence of human farm labor and it will provide the necessary data for research and development of the agricultural industry in Malaysia in the future. The limitations of the project can be overcome with future improvements to this project. Next, the scope of the project is clearly stated for the development of future greenhouses.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Automated greenhouse system is a system that can control the environment inside the parameter and monitoring the environment for development of plant growth. The main reason of doing literature review is to collect and reviewing the idea on how to develop an efficient automated greenhouse system.

A significant component of the horticulture and agriculture industries is the greenhouse. In our nation, greenhouse are utilized to grow plants under regulated climatic conditions, which either directly or indirectly control plant growth [7].

Moreover, the impact that will effect on human farm labor force. In addition, the data logging will make a system for botanist to develop their understanding about the growing of plant and consistently monitoring the environment for plant to grow.

2.2 History of Greenhouse

Table 2.1 Brief History of Greenhouse

1450	Artificial methods were used to grow Cucumis plants year-round for Emperor Tiberius. During chilly evenings, plants on carts were carried into enclosed buildings called Specularia. The royal physician of Korea's Joseon dynasty wrote the Sanga York text on crop husbandry.

1840	The Royal Horticultural Society's conservatories in Cheswick and Regent's Park in England are home to the massive wrought iron glasshouse buildings. The structural innovations of the 18th and 19th centuries greatly influenced greenhouse designs created in the 20th century.
1940	The majority of greenhouse structure designs were created to accommodate regional climatic conditions. In the Netherlands' Westland region, numerous large-scale commercial greenhouses sprang into operation during the 20th century.
1944	These greenhouses were substantially improved over the earlier models used for grape cultivation in the Netherlands, although they were inadequately insulated due to gaps between the plates. During World War II, the Westland greenhouses sustained major damage.
1952	These greenhouses were constructed to produce vegetables for both domestic consumption and export. Research partnerships established between the greenhouse industry and Wageningen University after the war further aided in advancing greenhouse technology.
1978	In China, protected vegetable and ornamental farming has increased. Chinese farmers were able to import contemporary greenhouse buildings like Venlo designs thanks to the open-door policy.

Based on table 2.1, the table explain briefly on the history of greenhouse [8].

2.2.1 Types of Greenhouse Have Been Constructed

2.2.1.1 Venlo Style Greenhouse

Figure 2.1 Venlo Style (Pure Green Farms, Indiana)

The Wide aluminum or steel trusses are used in the construction of Venlo-style greenhouses to give the necessary strength to withstand the region's frequent high winds and snow loads. Wide working areas are possible with the Venlo-style design because trusses eliminate the need for load-bearing posts. Additionally, the structure receives good sunshine penetration thanks to the design. In the Venlo greenhouses, irrigation with sprinklers and drainage systems eliminated the salt issue in the soil.

2.2.1.2 Solar Greenhouse

Figure 2.2 Solar Greenhouse (vegetablecropshotline.org)

The solar greenhouse with plastic glazing is a well-known low-cost building that was created in China. The region of Liaoning is where these lean-to or energy-efficient greenhouses first appeared.The solar greenhouses are passively heated by sunshine throughout the daytime and feature a sizable roof surface on the south side. To keep heat inside the building at night, a thermal blanket is draped over the greenhouse. The northern brick wall also keeps the heat inside the building.

2.2.1.3 Parral Style Greenhouse

Figure 2.3 Parral Style (inveramel.com)

Spain's Almeria region is where the parral-style greenhouse first appeared. These inexpensive buildings have low gutter heights and curving roofs wrapped with plastic. Metal strings are holding plastic film to the virtually flat ceiling. For summertime ventilation, the film can be rolled to the gutter. Rolling the material upward might also allow airflow from the sides.

According to research, Almeria's greenhouse zone is so large that the region's temperature is lowered by the white rooftops' strong sunlight reflection. According to measurements taken by NASA's Terra satellite since 1983, the area's albedo has grown, increasing solar reflectivity by 9% [8].

2.2.1.4 Gutter-Connected Polyhouse

Figure 2.4 Gutter-Connected Polyhouse (author's collection)

The area has climatic difficulties include extreme daytime and nighttime temperatures, high relative humidity, insects, and winds from monsoons and cyclones. The chosen greenhouse design consists of medium-to-tall, multiple-span, Gothic arch-shaped, gutter-connected polyethylene homes with side and roof ventilation.

Increased ventilation and shade netting are the major components of this design that reduce the temperature. Typically, an insect net is used to cover the permanent (open) roof ventilation. Thermal or shade screens are also employed to deflect sunlight and lower interior temperatures. All four sides of the greenhouse have side ventilation. During the monsoon season, the design provides protection from the wind and rain. The majority of the crops grown in these structures are for floriculture [8].

2.3 The Importance of Automated Greenhouse in Modern Agriculture

Traditional agricultural greenhouse management usually in Cameron Highland common use human to set and to adjust the lighting, irrigation system, cooling system and heating system. This approach not only results in increased management expenses but also a number of issues, such as poor production efficiency.

One of the main goals of the contemporary agricultural system is to maximize environmental conditions to promote plant growth with an improved yield in the shortest amount of time. Automation of a greenhouse allows for effective data collection and microclimate control. Additionally, it considerably minimizes the effort required for maintenance, making the method advantageous for small-scale farmers, gardeners, and agricultural researchers [9].

In view of present of disadvantages of greenhouse management. In the current agricultural sector, automation is being used more frequently. In order to eliminate human mistake and farm labor force dependence, it will connect people and "things." Automation is the process control that replaces human operators in industrial machines [7].

Moreover, a major trend in recent years has been a rise in interest in locally and organically produced food. Foods that are cultivated nearby are harvested when they are at their ripeness peak and are consequently flavorful. Additionally, growing food at home ensures that the food is truly organic. On the other hand, it requires a lot of time and work, and most individuals today do not have that [10].

2.4 The Importance of Control Environment and Monitoring for Strawberry Plant Growth

Modern agricultural techniques and sophisticated irrigation systems make it simple to produce any crop throughout the year, in any season. One such plant that need extreme care is the strawberry, which is only grown in regions of our country where the temperature ranges from 200 to 290 C and is most likely to produce fruit only in the months of October through November and April through May [11]. The high growth performance, higher nutrient uptake, and productivity of strawberry cultivars are modified by the use of natural soil medium combined with synthetic nutrient solution [12].

Environmental conditions of strawberry fields that are impacted by climatic changes, create and install a sensor network architecture that allows monitoring various climatic factors. Its production can be enhanced compared to traditional techniques. Information on variables and parameters is gathered from the device groups in order to monitor strawberry harvests. The percentage of soil moisture, ambient temperature, relative humidity, and soil pH level are all factors that are taken into account in the results. It may guarantee not only the control over them but also obtaining the quantities and qualities required [13].

2.5 Previous Work

This chapter provides a previous study related to greenhouse control system. Some researched have been done to gain information about the latest development greenhouse control system that had been developed. It is essential to comprehend how the hardware and software employed in the creation of the greenhouse control system work.

2.5.1 A Takagi-Sugeno Fuzzy Model for Greenhouse

Figure 2.5 Example Experimental Greenhouse Takagi-Sugeno Fuzzy

The modeling of the internal temperature of the greenhouse was based on a hybrid system. It was identified using the Takagi-Sugeno (TS) fuzzy model. In order to obtain the key modeling greenhouse parameters, clustering was used. In order to reduce the number of fuzzy rules used in the system modeling, a hierarchical strategy was used. It was developed to use neural network learning techniques for fuzzy modeling. In order to control hybrid systems with controlled switching, a nonlinear optimization-based algorithm and calculus of variations were combined.

The control of ambient temperature and relative humidity in greenhouses is described by simultaneous ventilation and heating system. The creation of a Takagi-Sugeno (TS) fuzzy model from a nonlinear dynamic model of the greenhouse in order to resolve the issue of bilinearity in greenhouse models. The stability analysis and control design issues can be reduced to a small number of sufficient conditions, which are expressed as linear matrix inequalities (LMIs), using the TS fuzzy model. Therefore, it is possible to control the greenhouse climate by using TS fuzzy models. Simulation results for numerous tests show the good performance and stability gained with the proposed design methodology are presented [14].

2.5.2 Greenhouse Control System By Korean Facility Management

Figure 2.6 Automated Korean Greenhouse

Korean facility management initially constructed this project. This project included specifications for the installation of their automated system, which requires the greenhouse's temperature and humidity to be recorded and allowed for automatic modifications, due to the delicate nature of growing plants in a greenhouse. They can use the Internet to remotely monitor and control the system as well. The controller will alert the administrator in the event of a failure, whether it be on the controller or auxiliary equipment. Each piece of equipment used in the system has substantial maintenance and purchase costs [15].

2.5.3 Comparison

Korean facility management initially constructed this project. This project included specifications for the installation of their automated system, which requires the greenhouse's temperature and humidity to be recorded and allowed for automatic modifications, due to the delicate nature of growing plants in a greenhouse. They can use the Internet to remotely monitor and control the system as well. The controller will alert the administrator in the event of a failure, whether it be on the controller or auxiliary equipment. Each piece of equipment used in the system has substantial maintenance and purchase costs [15].

Table 2.2 Comparison Between Other Project of Greenhouse

	Takagi-Sugeno Fuzzy Model	**Greenhouse Control System By Korean Facility Management**	**Development of Automated Greenhouse System For Strawberry Plants Powered By Solar Energy**
Control the temperature and humidity	Temperature and humidity can be control automatically	Temperature and humidity can be control automatically	Temperature and humidity can be control automatically
Remote monitoring system	Not available for remote monitoring	Available for remote monitoring through internet	Not available for remote monitoring
Data logging capabilities	Not available for data logging	Not available for data logging	Available for data logging

Based on table 2.2, it shows the comparison between greenhouse temperature and humidity control system by Takagi-Sugeno Fuzzy model and Korean facility management. According to the comparison. The development of automated greenhouse for strawberry plants powered by solar energy is able to collect and store the data from various sensor.

2.6 Chapter Summary

Based on this chapter, it shown a very good references towards the development of automated greenhouse system for strawberry plants powered by solar energy. Moreover, this literature review shown an impact towards the human farm labor when implementing the automated system. In addition, constant monitoring using this system is required for future development based on literature reviewed. As a conclusion, this project will show a significant impact on future agriculture industries. Hence, it will modernize the domestic greenhouse system in Malaysia.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discusses about the full methodology of the overall project. This chapter will describe about the block diagram, flow chart, and hardware architecture of the project that consists the hardware design and the software implementation. This chapter also will discuss about the entire component used to develop the automated greenhouse system from starting the project until end of project.

3.2 Block Diagram

Table 3.1 Block Diagram

INPUT	PROCESSOR	OUTPUT
 Soil Moisture Sensor	 Arduino Uno	WATER PUMP SYSTEM  Water Pump Motor
 Light Intensity Sensor (LDR)		LIGHT SPECTRUM  LED Strip
 DHT- 22		WATER COOLING SYSTEM  Peltier Thermoelectric Cooler Fan

		 Cooling Motor  Cooling Radiator with Fan

Based on the table 3.1, the central processing unit of the automated greenhouse system is the Arduino Uno microcontroller board, utilizing the ATmega328P chipset. This versatile board is programmable through the Arduino Integrated Development Environment (IDE). In its role as the system's computational hub, the Arduino Uno manages calculations, sensor inputs, and actuator outputs.

The system employs various sensors for data acquisition, including the DHT-22 for measuring temperature, relative humidity, and heat index within the model. The corresponding actuator for the DHT22 consists of a Peltier Thermoelectric Cooler Fan, Cooling Motor, and Cooling Radiator with Fan.

Additionally, a soil moisture sensor is integrated to gather data on soil moisture content. The actuator associated with this sensor is a 12V water pump motor, regulating the water flow from the tank to the strawberry plant according to predefined moisture levels.

Furthermore, a light intensity sensor (LDR) captures lux data to assess brightness levels. The corresponding actuator for the LDR is a 12V LED, designed to activate if the ambient brightness falls below the optimal level for strawberry plants.

This comprehensive setup, orchestrated by the Arduino Uno, forms the backbone of the automated greenhouse system, ensuring seamless communication and interaction between sensors and actuators to maintain optimal growing conditions for the plants.

3.3 System Process

The system procedure for measuring soil moisture, light intensity, temperature, and humidity includes using sensors to continuously monitor these environmental variables. To provide the best conditions for strawberry plants to flourish, the data is analyzed, compared to predetermined thresholds or ranges, and control measures are implemented. Based on the observed values, the automation system modifies the irrigation, lighting, heating, cooling, humidification, and dehumidification systems, enabling precise control and effective resource management inside the greenhouse.

3.3.1 Soil Moisture

The system moisture is a crucial factor in the growth and flourishing of strawberry plants. During their initial establishment phase, strawberry plants should have soil moisture levels closer to the higher end of the range, between 80% and 90%. When the plant matures and begins to bear fruit, gradually reduce soil moisture to between 70% and 80% [4].

Soil moisture sensors have been set up in the greenhouse to measure the soil's moisture content and continuously capture data on the moisture content of the soil. The data is processed and examined to determine the present soil moisture condition. If the soil moisture drops below the desired level, the control system starts the irrigation mechanism to hydrate the plants. The irrigation procedure is altered based on the measured soil moisture levels to ensure that the strawberry plants receive the correct amount of moisture.

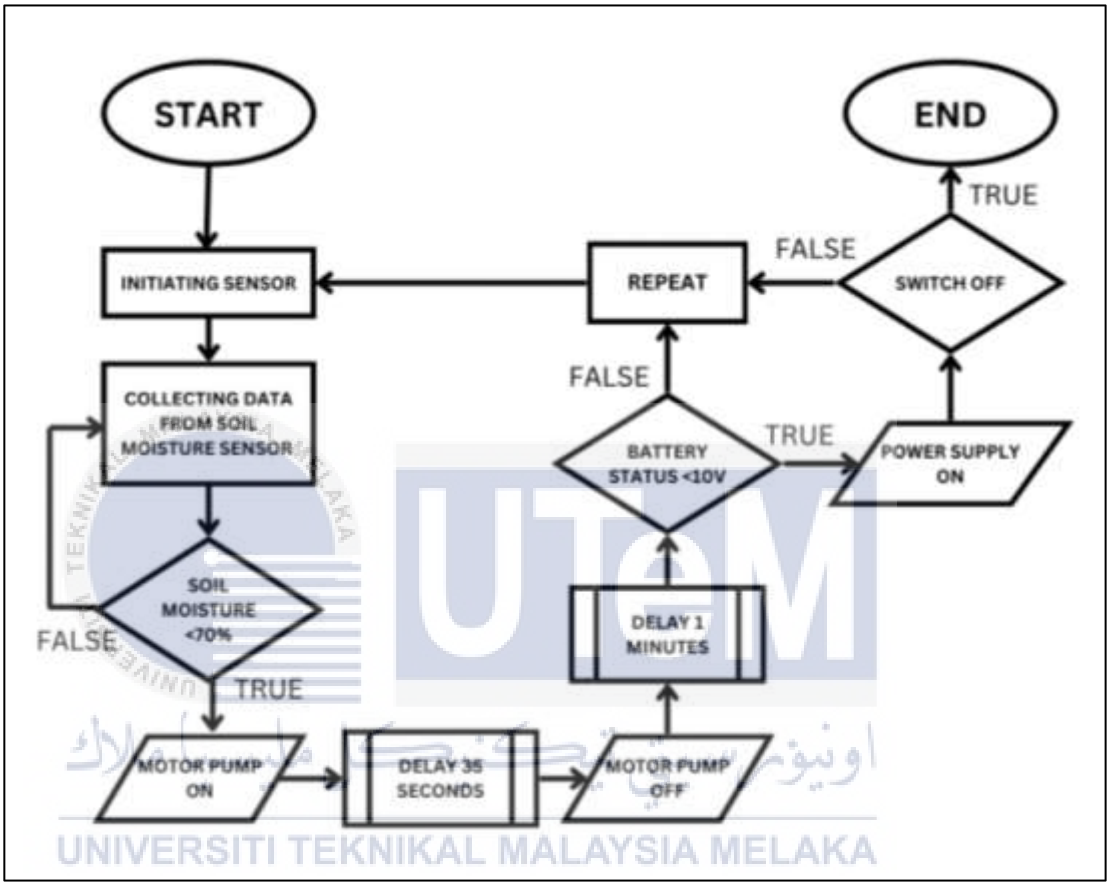


Figure 3.1 Flowchart of Soil Moisure

For this project, the required level of soil moisture is 70%, if this level is not met, the system will begin pumping water from the tank through the tube to the ground inside the model.

3.3.2 Light Intensity

Another important element that has a significant impact on strawberry plants' growth and development is light intensity. Strawberries grow best in high light levels because they are a plant that needs full sunshine for optimum growth. Strawberry plants usually need at least 6 to 8 hours of direct sunlight every day. For the best growth and fruit production, strawberry plants normally need a minimum of 10,000 to 15,000 lux of light [16].

The light intensity in the greenhouse is measured using light sensors or lux meters to assess the lighting conditions. The collected data is analyzed and compared to predetermined optimal ranges for strawberry plants. If the light intensity is insufficient, additional lighting devices like LEDs or artificial grow lights are activated. The length and intensity of the lighting are adjusted based on observed light levels and the growth stage of the strawberry plants to ensure they receive the right amount of light for their growth and development.

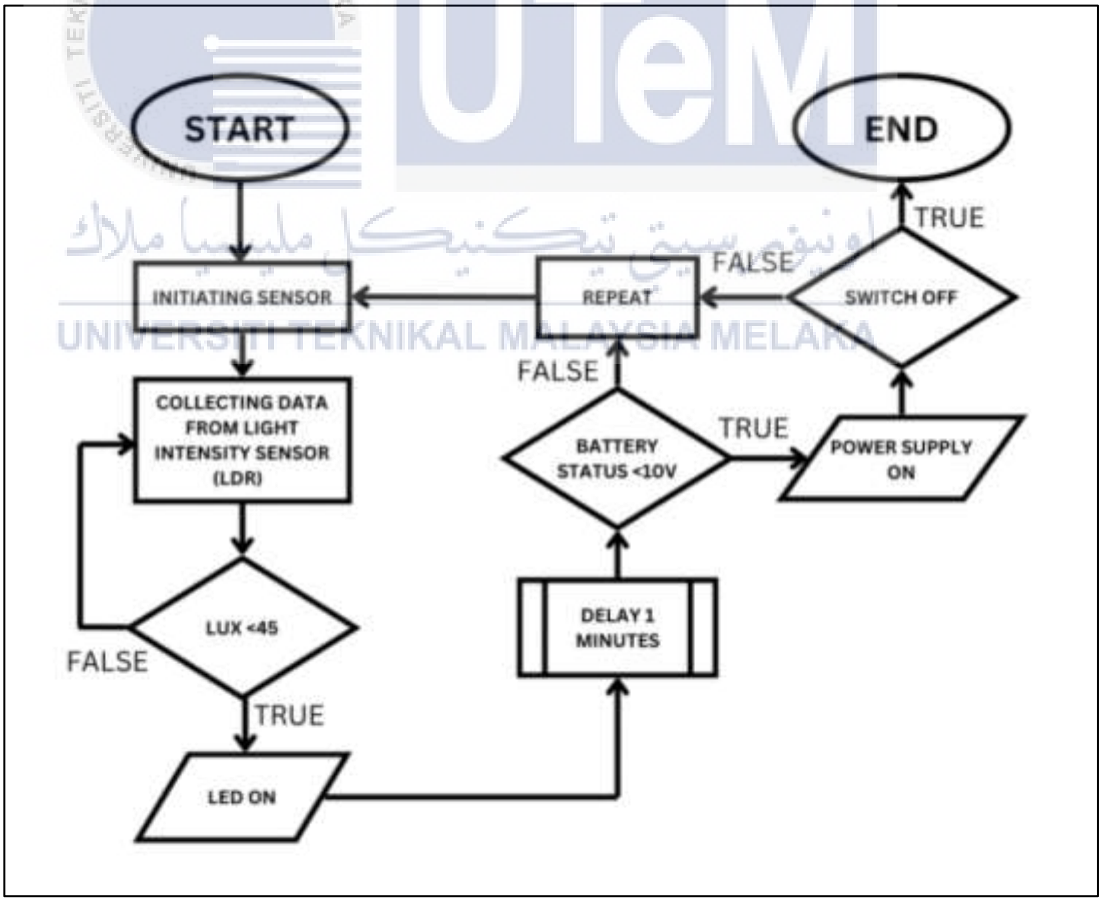


Figure 3.2 Flowchart of Light Intensity

The system will start collecting sunlight illumination (lux) data from outside of greenhouse model. If the light intensity below than 45 lux, the system will activate the LED strip.

3.3.3 Temperature

The Temperatures that favour healthy growth, flowering, and fruit production are ideal for strawberry plants. Temperatures between 60°F and 75°F (15°C to 24°C) are typically optimal for the vegetative growth stage, which includes the development of leaves and runners [2]. This temperature range promotes robust leaf development and overall plant growth.

The temperature sensors placed in the greenhouse monitor real-time temperature variations. The collected data is analyzed and compared to predefined ranges for strawberry cultivation. If the temperature deviates from the desired range, the control system activates heating or cooling mechanisms to regulate the temperature using fans, vents, or HVAC systems. The heating or cooling processes are continually adjusted based on the measured temperature to maintain an optimal and suitable environment for the growth of strawberry plants.

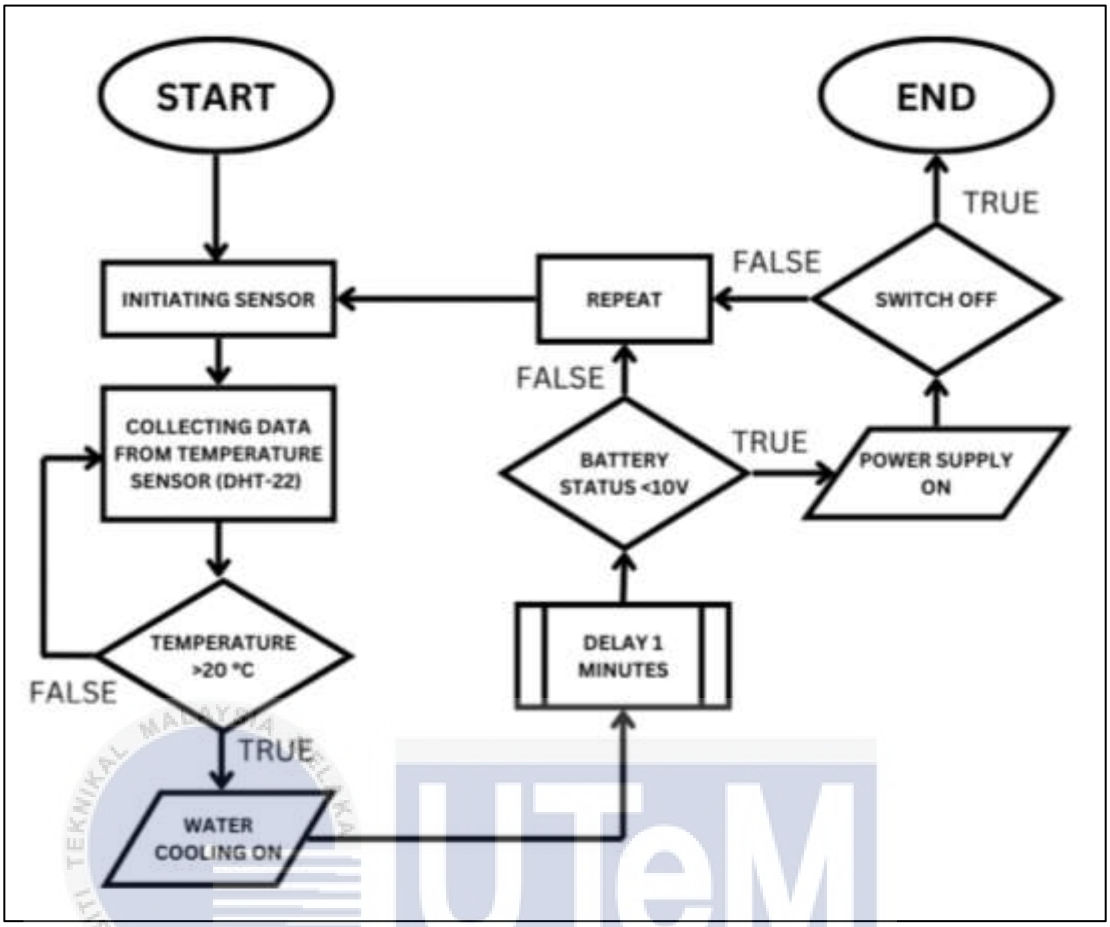


Figure 3.3 Flowchart of Temperature

The system will begin gathering information on greenhouse model air temperature. The water cooling system will automatically turn on to cool down the environment within the model if the temperature rises by more than 20°C.

3.3.4 Humidity

Another environmental component that has a big effect on strawberry plants growth and health is humidity. Generally speaking, strawberry plants flourish in environments with moderate humidity levels between 40% and 70% [2]. This variety offers the perfect compromise, ensuring appropriate moisture without being overly damp, which can promote the growth of disease.

Humidity sensors monitor and collect data on relative humidity levels in the greenhouse. The data is analyzed to determine the current humidity status. Control algorithms compare the measured humidity with predefined optimal ranges for strawberry plants. If the humidity deviates from the desired range, the control system activates humidification or dehumidification mechanisms, such as misting systems or dehumidifiers, to regulate the humidity. These processes are continuously adjusted based on the measured humidity to maintain the optimal humidity range, ensuring the best conditions for the growth and development of strawberry plants.

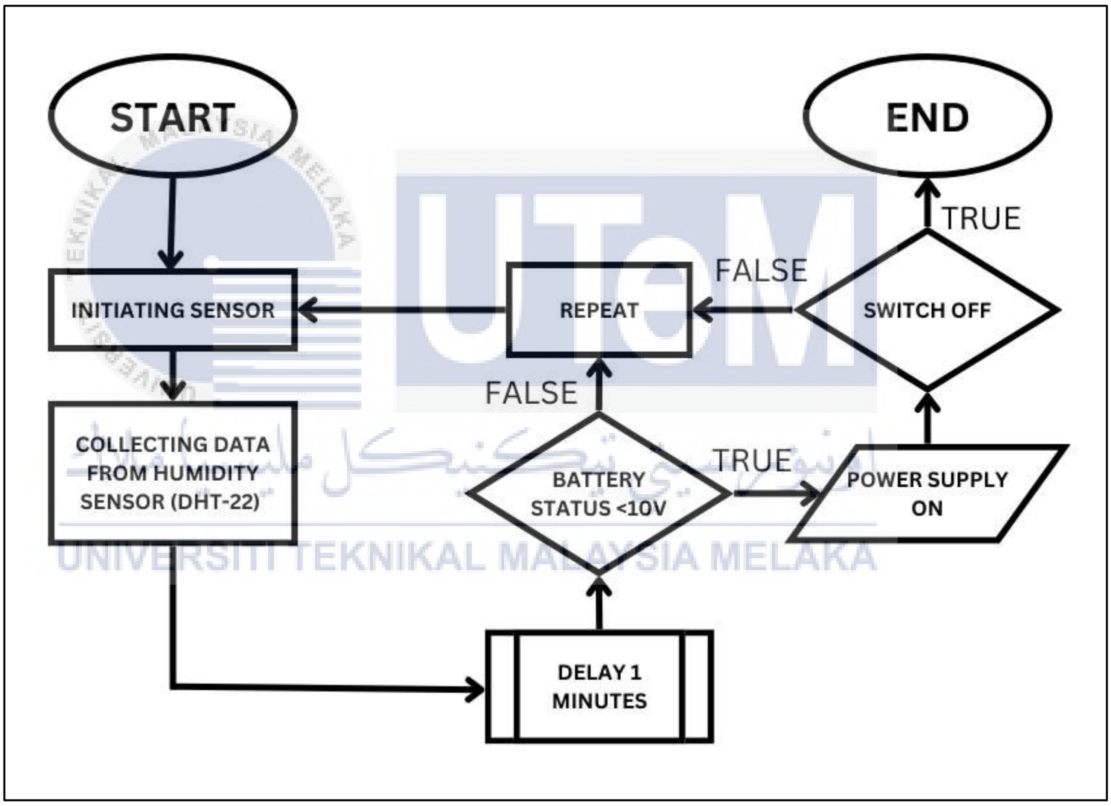


Figure 3.4 Flowchart of Humidity

The system will start gathering information about the greenhouse model's relative humidity. Additionally, utilising information gathered from ambient temperature and relative humidity, Arduino Uno will calculate heat index.

3.4 Overall Project

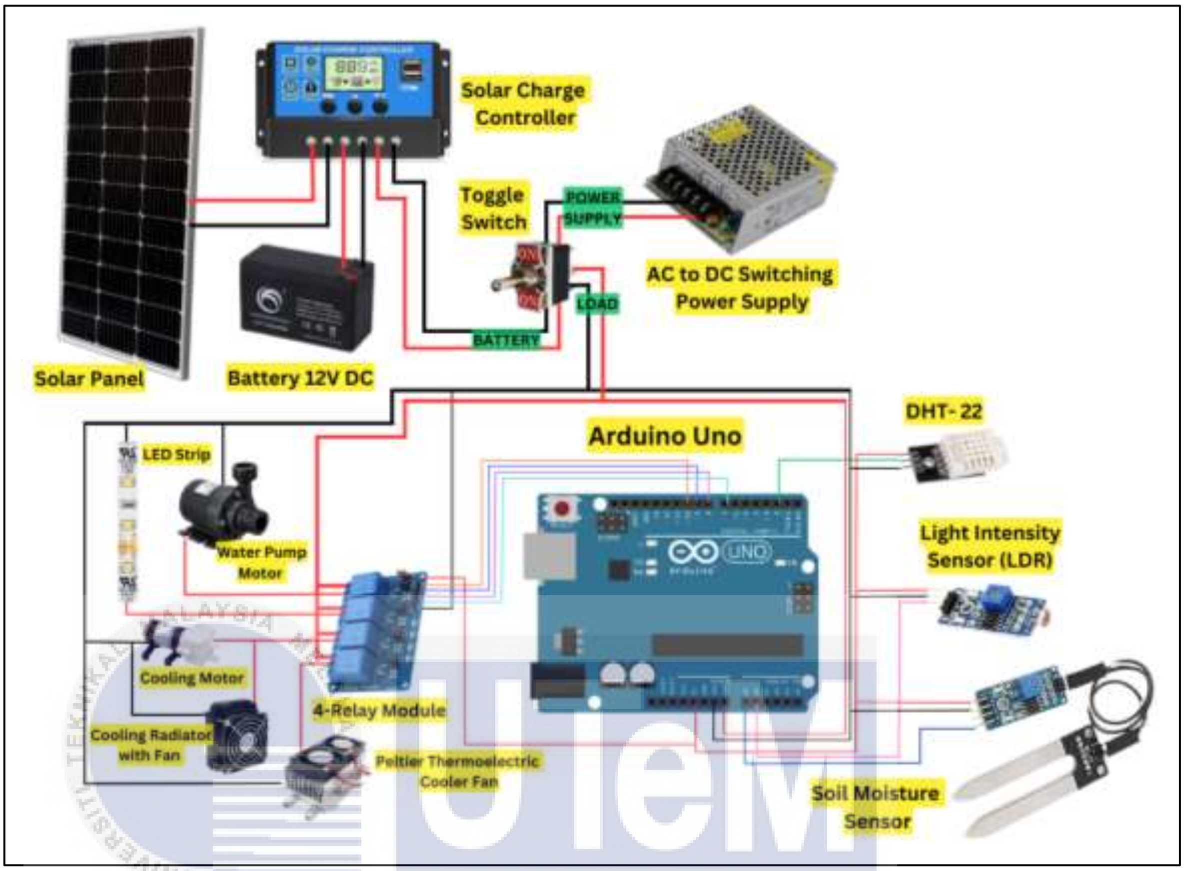


Figure 3.5 Overall Project Diagram

Project overview for an automated greenhouse system for strawberry plants powered by solar energy. Greenhouse structure design, combining features for temperature and humidity control, soil moisture and light intensity. Automatic generation of data monitoring and analysis systems for environmental parameters and growth of strawberry plants.

The power supply for activating the greenhouse system is sourced from two distinct energy channels: conventional power supply and solar energy. Solar energy is harnessed through batteries charged by solar panel systems. Solar charge controllers, integral to this system, incorporate protective mechanisms to safeguard batteries and solar infrastructure.

Conversely, the non-solar energy source is facilitated by a switching power supply. This power supply is adept at converting alternating current (AC) to direct current (DC) while delivering a regulated 12-volt output with a maximum current of 5 amperes. The power supply system efficiently manages the conversion process, ensuring a consistent voltage supply for electronic devices. Activation of the greenhouse system can be change between these two energy systems using a dedicated toggled switch, allowing for flexibility and control in power sourcing.

3.4.1 Project Flowchart

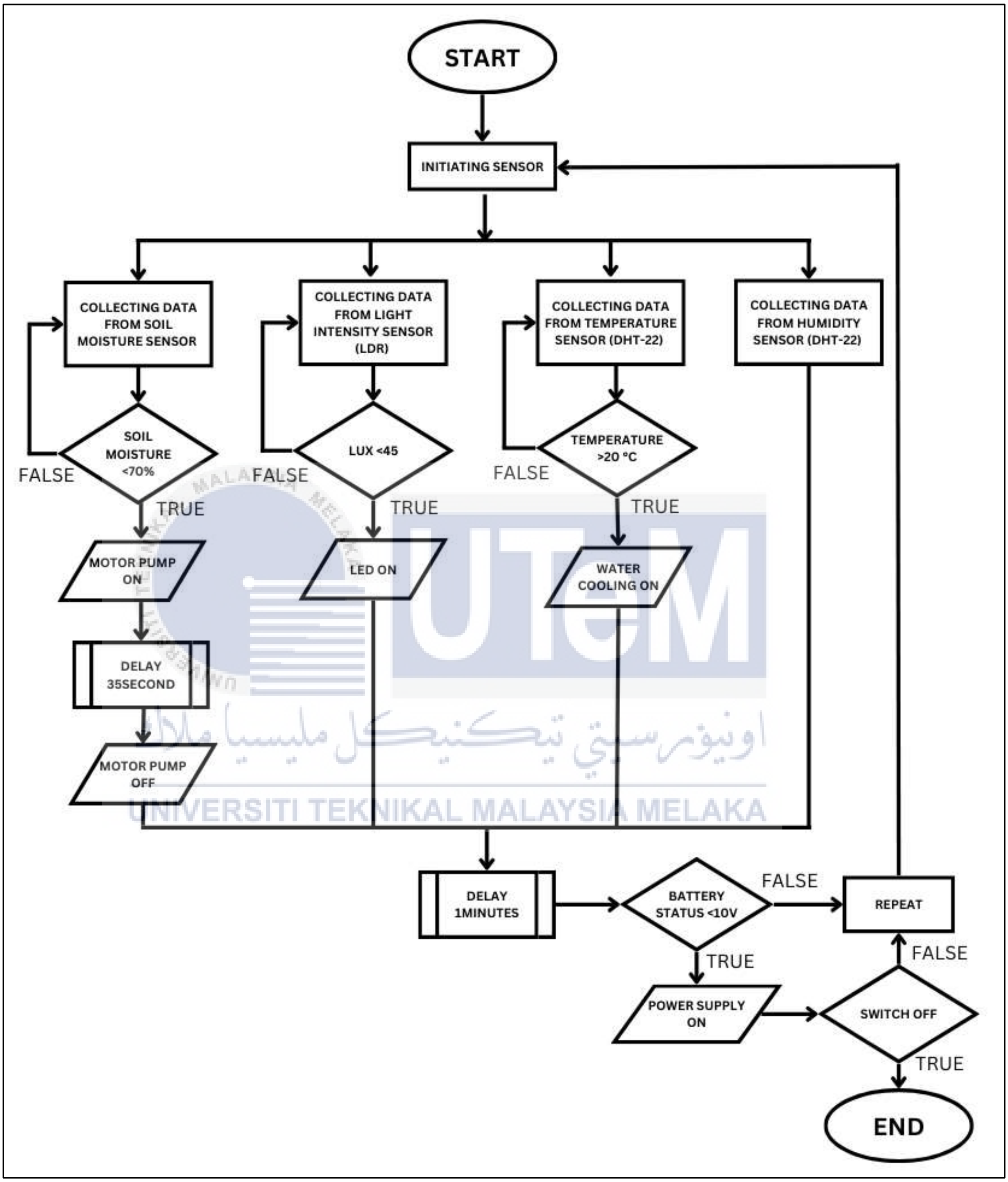


Figure 3.6 Flowchart

Based on the figure 3.6, When the system is start Arduino Uno will initiate the sensor. But If the battery is below than 10V, the system will stop it operation. but the greenhouse system can be turned back on when switching to a switching power supply. The system will stop if the switch is placed in the off position. If the switch is placed back in the on position, the system will come back to life and the program will start collecting data from the sensors.

a) Collecting data from soil moisture sensor

When the The system will start collecting soil moisture contain in the soil inside the greenhouse prototype. If the percentage of soil moisture contain below than 70% the system will start pumping the water from the tank through the tube onto the soil inside the model. Lastly, data will be collected in 6minute interval.

b) Collecting data from light intensity sensor (sunlight illumination)

The system will start collecting sunlight illumination (lux) data from outside of greenhouse model. Arduino Uno will convert the reading from photo resistor (analogue read) into lux using mathematical formula.

Lux = (250.000000/ (ADC_value*analogRead(sunlightPin)))-50.000000.

If the light intensity below than 45 lux, the system will activate the LED strip.

(coding can be referred to appendix B)

c) Collecting data from DHT22 (temperature)

The system will start collecting air temperature data within the greenhouse model. If the temperature increase more than 20°C it will automatically switch on the fan to cool down the environment inside the model.

d) Collecting data from DHT22 (humidity)

The system will start collecting relative humidity data within the greenhouse model. Moreover, Arduino Uno will compute heat index using collected data from air temperature and relative humidity.

3.4.2 Circuit Diagram

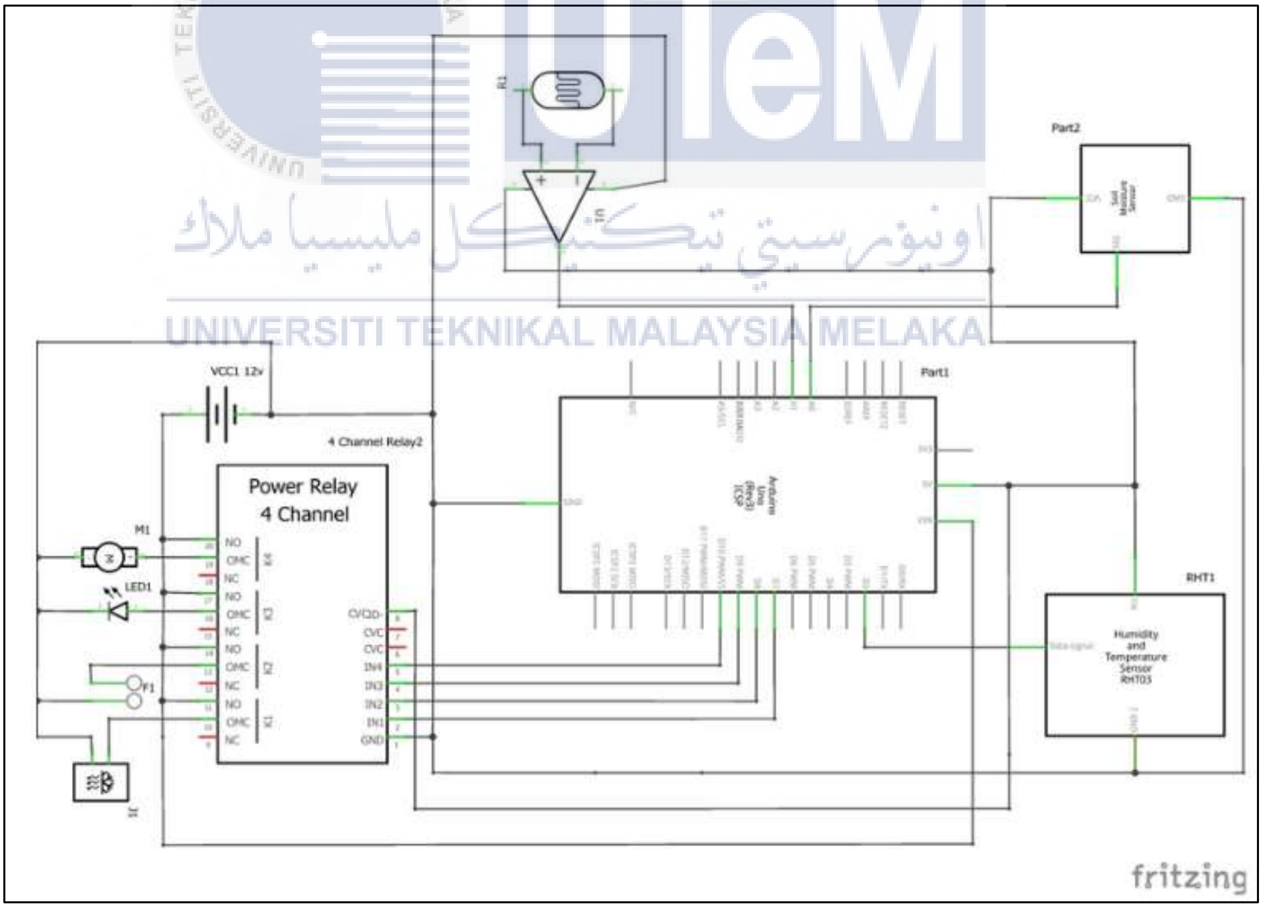


Figure 3.7 Circuit Diagram

Based on figure 3.7. The circuit will be connected to 12V battery. Arduino Uno input voltage range is 7 to 12 volts. This can be supplied through the DC power jack or the Vin pin.

a) Connection of Light Intensity Sensor

Table 3.2 Connection of Light Intensity Sensor

Light Intensity Sensor	**Wiring to Arduino Uno (pin)**
VCC	5V
Output pin	Analogue pin A1
GND	GND

b) Connection of DHT22

Table 3.3 Connection of DHT22

DHT22	**Wiring to Arduino Uno (pin)**
VCC	5V
Output pin	2
GND	GND

c) Connection of Soil Moisture Sensor

Table 3.4 Connection of Soil Moisture Sensor

Soil moisture sensor	**Wiring to Arduino Uno (pin)**
VCC	5V
Output pin	Analogue pin A0
GND	GND

d) Connection of 4-Relay Module

Table 3.5 Connection of 4-Relay Module

4-Relay Module	Wiring to Arduino Uno (pin)
VCC	5V
IN4	10
IN3	9
IN2	8
IN1	7
GND (ground)	GND (ground)

3.5 Hardware Implementation

To accomplish this project, several types of hardware have been used to the system as the system become more reliable and compatible. Our greenhouse provides an alternative for the eco-system to save cost and electricity consumption. The various types of hardware used in the system are enumerated below:

3.5.1 Arduino Uno

Figure 3.8 Arduino Uno

The Arduino micro controller is the main component which all the devices connect with it. Arduino UNO control all the whole system features and interfacing all the components in this system. Such as DHT22, soil moisture sensor, light intensity sensor.

3.5.2 DHT- 22

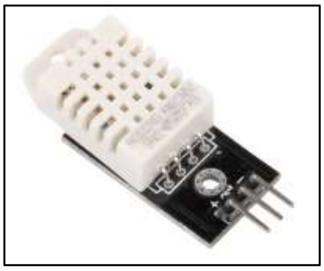


Figure 3.9 DHT-22

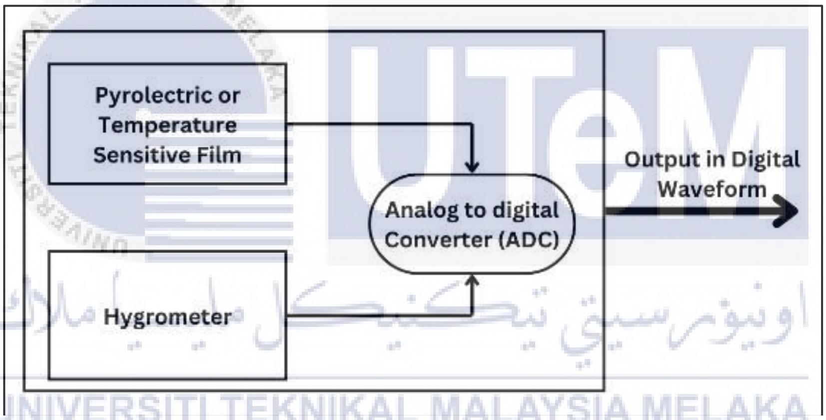


Figure 3.10 Temperature and Humidity Sensor Node

Based on figure 3.10, this node senses the temperature and humidity inside the greenhouse using a pyroelectric film for temperature and a hydrometer which is a resistive type of humidity sensors that monitor changes in the resistance value of the sensor element in response to the change of humidity. The changes recorded by both are sent to a common ADC system which will convert the analogue form of data to digital form which is easy to decode and understandable by the server. For automated greenhouse system, DHT-22 sensor which is a composite sensor containing a calibrated digital signal output of the air temperature, air humidity, and heat index. It can be operated in the temperatures till 50°C and humidity till 80% of relative humidity.

3.5.3 Soil Moisture Sensor

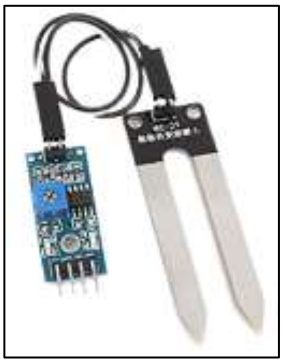


Figure 3.11 Soil Moisture Sensor

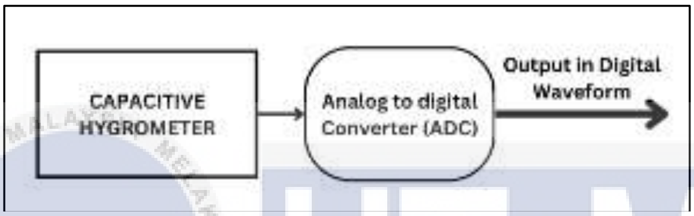


Figure 3.12 Soil Moisture Sensor Node

Based on the figure 3.12, the node senses the moisture content based on capacitive effect, it consists of a hydroscopic dielectric material between a pair of electrodes forming a capacitor. Then relay will amplify the voltage to be read as analogue input. At wet soil condition, the dielectric constant of water vapour has a value of about 80%, which is much larger than the constant of dielectric material, therefore, absorption of water vapour by the sensor results in an increase in sensor capacitance. Thus, moisture content is a function of water vapour pressure. Therefore, there is a relationship between soil moisture content, the amount of moisture present in the sensor.

3.5.4 Light Intensity Sensor (LDR)

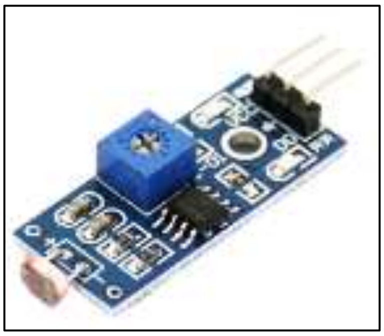


Figure 3.13 Light Intensity Sensor (LDR)

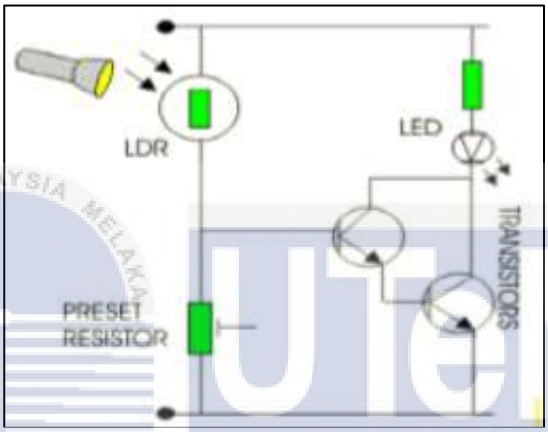


Figure 3.14 Light Intensity Sensor (LDR) Node

Based on figure 3.14, a LDR is a semi-conducting material. By radiating a light onto an LDR, the light will provide energy to the semiconductor and be immersed by covalent bond electrons. This energy will breakdown the bonds between atoms. The electrons will breakdown and are allowed to move freely within the LDR. This delivers to a bigger current flowing in the semiconductor. Thus, the resistance of a LDR will decrease due to increasing Illumination.

3.5.5 4-Relay Module

Figure 3.15 4-Relay Module

The 4-Relay modules provide low-power signals to regulate high-power loads. It enables the switching of high-power devices or circuits to be controlled by low-power signals. The electromechanical relay is activated when the control signal is applied by the relay module, which then opens or closes the contacts to connect or detach the high-power load.

3.5.6 Motor Pump 12V DC

Figure 3.16 Motor Pump

Motor pump is use to control the water flow for plant irrigation. DC 12V motor pump is use to pump the water from the tank to create enough pressure to flow through the tube to the greenhouse. Then relay is use to control the water flow.

3.5.7 LED Strip

Figure 3.17 LED Strip

DC 12V LED strip is use to create artificial sunlight when low sunlight intensity. LED strip is low power consumption and cost effective.

3.5.8 Thermoelectric Peltier Cooler

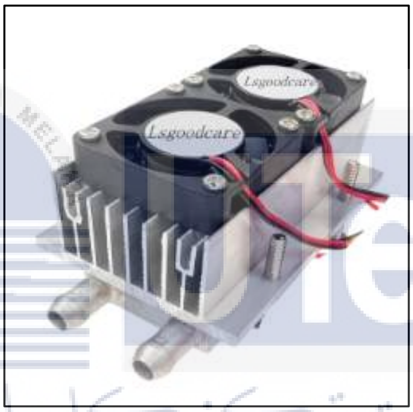


Figure 3.18 Thermoelectric Peltier Cooler

A Thermoelectric Peltier Cooler functions by exploiting the Peltier effect in semiconductor materials. When an electric current is applied, the device absorbs heat at one side (cold side) and releases it at the other side (hot side). This makes it possible to use it for heating and cooling purposes. When chilling, the cold side comes into touch with the intended object or area and absorbs heat to produce a cooling effect. On the other hand, the hot side is used to release heat during heating. Because of its tiny size and lack of moving components, this device is ideal for applications like small refrigerators and portable coolers, as it provides perfect temperature control through the modulation of electric current.

The Peltier from the hot side will heat the heat sink block and at the same time, the liquid in the tube flowing from the cooling motor pump enters the heat sink block, doing the process of reducing the heat, then the liquid goes out to the cooling radiator. While the Peltier from the cold side will spray cold air from the fan and cool the temperature in the greenhouse.

3.5.9 Cooling Motor Pump

Figure 3.19 Cooling Motor Pump

The primary function of a cooling motor pump is to maintain an optimal operating temperature by continuously moving the cooling fluid through the system. The warm coolant is drawn by the pump from the heat-generating elements and circulated via a radiator or heat exchanger as part of a cooling system. As the coolant flows through the system, heat is transferred to the surrounding air or another medium, effectively cooling the fluid.

3.5.10 Cooling Radiator Fan

Figure 3.20 Cooling Radiator Fan

The cooling radiator fan is a crucial component in maintaining optimal temperatures within electronic system. This electrically powered fan is mounted behind the radiator and, while the fan is operating at a low speed, it automatically turns on to improve airflow. The fan helps the coolant or cooling fluid dissipate heat by forcing air through the radiator, so averting overheating. The cooling radiator fan is essential for preserving temperature management, which ultimately enhances system dependability and guards against potential harm from extreme heat.

3.5.11 Battery 12V

Figure 3.21 Battery 12V

The amount of charge a 12V battery can store and deliver over a certain time period is referred to as its capacity. A 12V battery is made to consistently produce 12 volts of output voltage. This voltage level is often used in a variety of applications, such as solar systems and small electronic devices.

3.5.12 Solar Charge Controller

Figure 3.22 Solar Charge Controller

Solar charge controllers incorporate protection mechanisms to safeguard the battery and solar system. It makes sure the batteries get the best possible charging voltage and current, avoiding overcharging and over discharging, which can harm the batteries.

3.5.13 Solar Panel

Figure 3.23 Solar Panel

A solar panel referred to as a photovoltaic (PV) panel, is a device that uses the photovoltaic effect to converts sunlight into electricity. Solar panels are made to capture sunlight and transform it into useful electricity in order to provide electrical power. Additionally, solar panels are essential for capturing clean, sustainable solar energy.

3.5.14 Switching Power Supply (AC to DC)

Figure 3.24 Switching Power Supply

The switching power supply serves to convert alternating current (AC) into direct current (DC) while delivering a regulated 12-volt output with a maximum current of 5 amperes. This power supply efficiently manages the conversion process, ensuring a stable voltage for electronic devices. With a power rating of 60 watts, it can handle loads up to this limit, making it suitable for various applications where a reliable and regulated 12V power source is required. The switching power supply is also ideal for applications with limited space because of its efficiency-focused design and often small form factor.

3.5.15 Toggle Switch

Figure 3.25 Toggle Switch

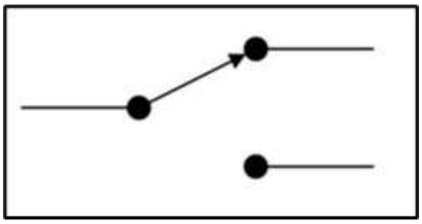


Figure 3.26 Single Pole Double Throw (SPDT)

A 3-pin toggle switch is a manual control with three connection points: common, normally open, and normally closed. It can toggle between two different circuit configurations. In one position, it connects common to normally open, completing a circuit, and in the other position, it connects common to normally closed, interrupting the circuit. This switch is useful for controlling two separate paths or devices with a single toggle.

Based on the figure 3.26, 3-pin toggle switch is a Single-Pole, Double-Throw (SPDT) switch that provides three positions. In the middle position of the switch is in the neutral state, the load output is connected to this pin. for the top pin is connected to the battery and the bottom pin is connected to the power supply. When toggled up, it connects the power supply to the load. On the other hand, when toggled to the lower side, it connects the battery to the load, creating a different circuit. This configuration allows control between two sets of contacts, making it ideal for applications where the user needs to choose between two different connections or states.

3.6 Circuit Simulation

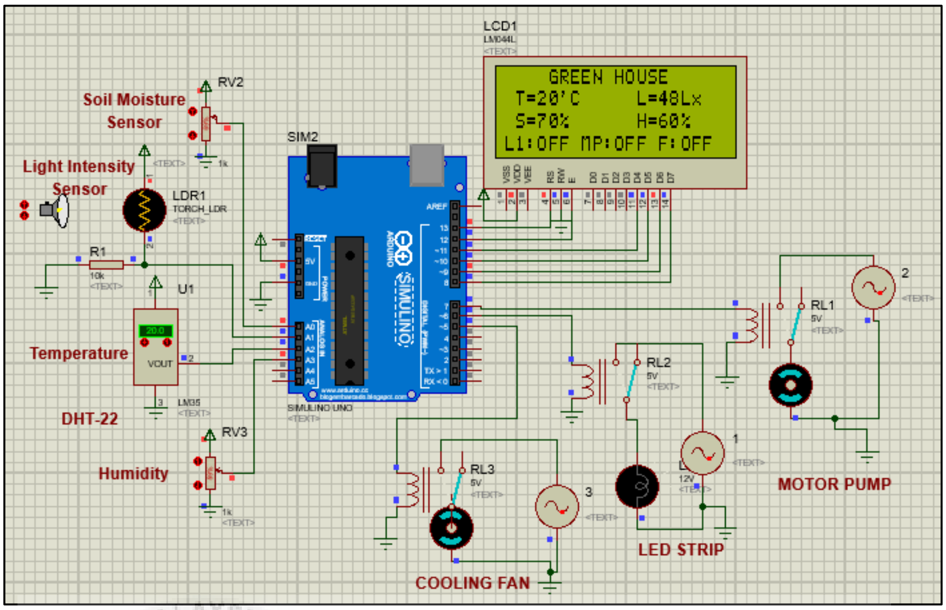


Figure 3.27 Initial Simulation Experiments using Proteus 8 Software

This simulation circuit's goal is to determine whether the automatic greenhouse system is functioning properly and to obtain preliminary result. The Arduino Uno serves as the circuit's central hub, to which all other components are connected. The DHT-22, Soil Moisture Sensor, and Light Intensity Sensor (LDR) are the sensors utilized as inputs in this circuit. Relays are used to switch and control low-power signals on and off for high-power devices and circuits. All sensors' reading results are displayed using liquid crystal displays (LCDs), which are also utilized to show whether motor pumps, fans, and LED strips are running ON or OFF.

3.7 Hardware Development

3.7.1 Product Sketch

Based on Figure 3.28, the product sketch is the basis of this product.

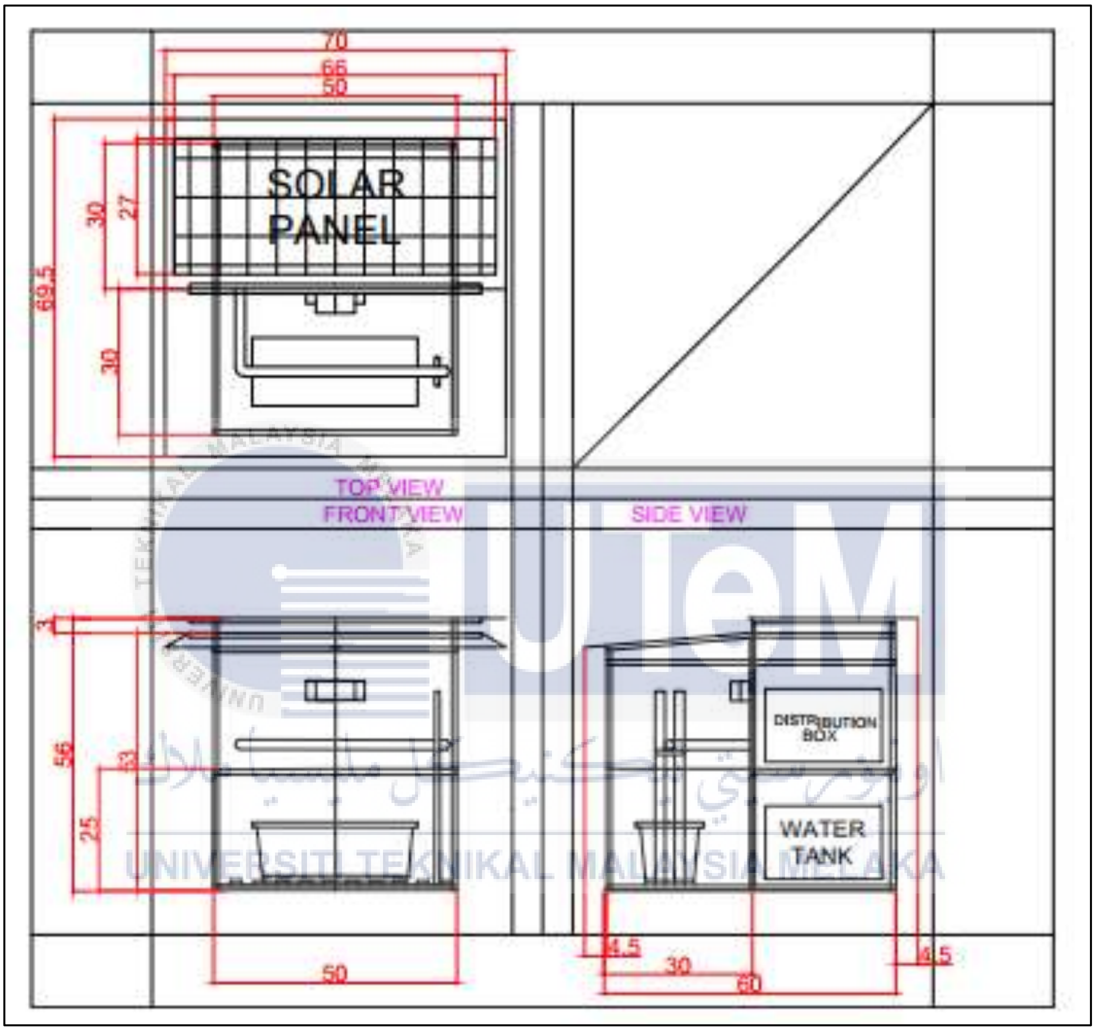


Figure 3.28 Product Sketch using Autocad

3.7.2 Building Prototype

The main material for building a greenhouse is wood and a flat transparent roof because wood is cheaper and easier to design and a flat transparent roof is easy to paste.

Figure 3.29 Building Prototype

3.7.3 Circuit Development

The circuit is tested on breadboard to check the functionality and to test the integration between software and hardware. This test is crucial to determine the problem before solder onto printed circuit board (PCB).

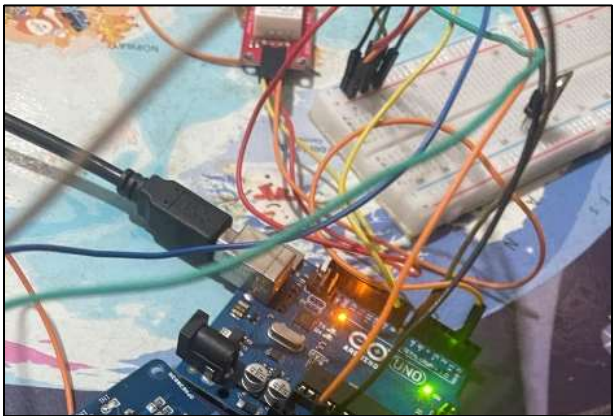


Figure 3.30 Testing Circuit on Breadboard

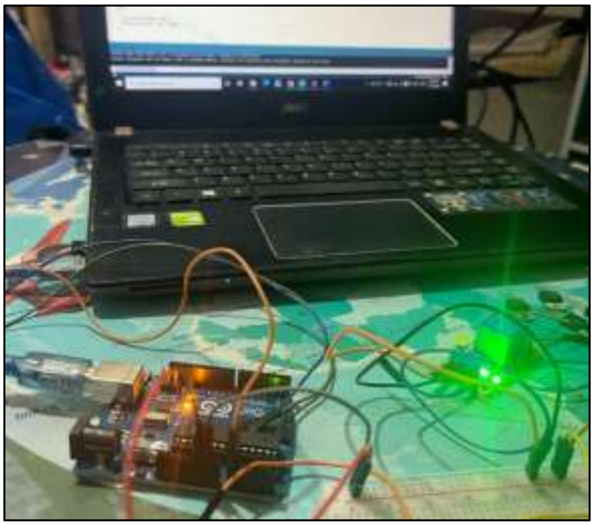


Figure 3.31 Circuit Testing with All Sensors

3.7.3.1 Testing Water Pump

Figure 3.32 Testing Functionality of Water Pump

Figure 3.33 Test the Water Pump Pipeline

3.7.3.2 Testing LED

Figure 3.34 Testing Functionality of LED

3.7.3.3 Testing Water Cooling

Figure 3.35 Testing Functionality of Water Cooling System

Figure 3.36 Water Cooling System Cool Down the Greenhouse Temperature

3.7.4 Soldering Circuit on PCB

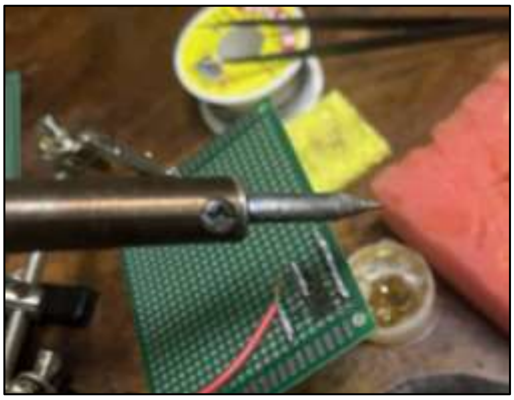


Figure 3.37 Soldering the Components on PCB

3.7.5 Soil Mixture for Strawberry Plants

Figure 3.38 Making a Soil Mixture

Figure 3.39 Monitor the Growing Condition of Strawberry Plants

3.7.6 Testing Solar Panel

Figure 3.40 Testing Solar Panel

Figure 3.41 Measures Solar Irradiance Levels

3.8 Prototype Product

3.8.1 Top View

Figure 3.42 Top View

Figure 3.43 Top View Distribution Box Section

Figure 3.44 Top View Plants Section

3.8.2 Front And Back View

Figure 3.45 Front View

Figure 3.46 Back Side View

Figure 3.47 Back Side View Distribution Box and Water Tank Section

3.8.3 Right And Left Side View

Figure 3.48 Right Side View

Figure 3.49 Left Side View

3.9 Limitation of the Proposed Methodology

The methodology used in the "Development of Automated Greenhouse System for Plants Powered by Solar Energy", it does have some limitations. The system heavily relies on sunlight, making it susceptible to variations in weather conditions and geographical factors. Initial setup costs for solar panels might be a hurdle, and the complexity of integrating multiple components could pose challenges in maintenance and understanding.

The system's adaptability to different crops and compliance with regulations should be carefully considered. Additionally, it operates optimally during daylight hours, requiring supplementary power for nighttime use. These limitations highlight areas for improvement and careful consideration as the system is implemented and refined over time.

3.10 Summary

This chapter presents the proposed methodology in order to develop a new, effective and integrated approach in estimating large scale/system wide TL of medium voltage (MV) network. The primary focus of the proposed methodology is in accomplishing a simple, less rigorous and effective estimation in such a way that it would not cause a significant loss of accuracy of the results. The methods also intended to use the generally available and limited data of the network and load from the power utilities. The ultimate intend of the method is not to obtain highest accuracy, but, for efficiency, easy to use and manipulate and practicality of deployment on a large scale distribution network.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

Based on this chapter it will display the result achieved by the project of the Development of Automated Greenhouse System for Strawberry Plants Powered by Solar Energy. The objective of the analysis is to explain about the result and to confirm that the project objectives are accomplished.

4.2 Overall Result

4.2.1 Dry to Wet Soil Condition

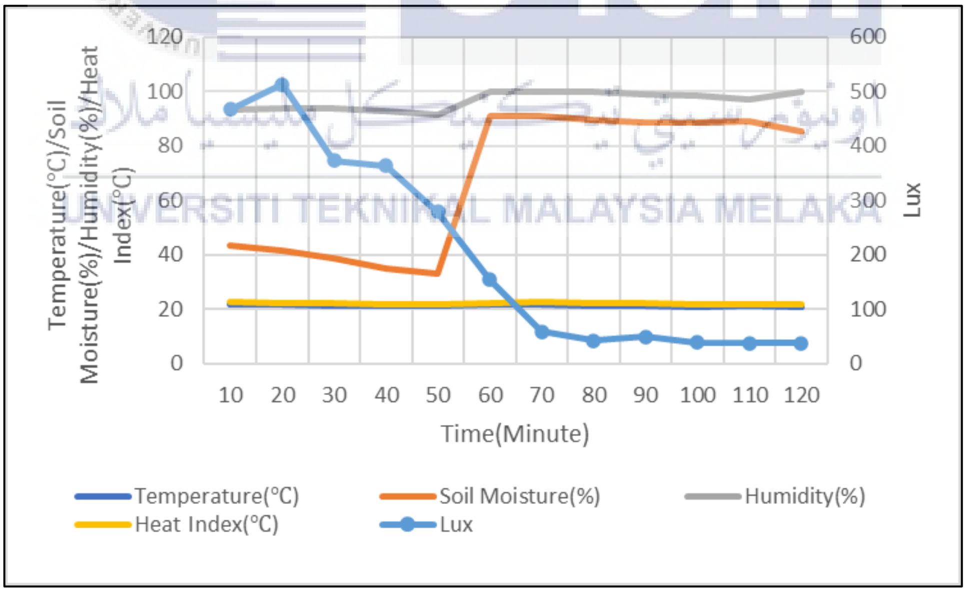


Figure 4.1 Dry To Wet Soil Condition

Based on figure 4.1, shows as overall result that has been collected from the data logger, data is taken at 3 pm to 5 pm. This graph illustrates the changes in temperature, heat index, soil moisture, humidity, and lux over a period of 2 hour or 120 minutes. The temperature and heat index are measured in °C, soil moisture and humidity in %, and lux is a measure of illuminance.

For light intensity, measured in Lux, over time. The Lux value starts at around 512.64 and decreases sharply to 278.21 at 70 minutes. After 70 minutes of cloudy weather, the graph shows a significant decrease in Lux levels, indicating a reduction in light intensity. The Lux levels drop from 278.21 at 70 minutes to as low as 37.14 at 120 minutes.

For soil moisture percentage over time. Initially, the soil moisture decreases gradually until it reaches below 30% at 50 minutes. At this point, a pump is turned on for 5 seconds to irrigate the soil from a water tank, causing a rapid increase in soil moisture to above 90%. The soil then remains very moist for the duration of the measured time.

For humidity over time. The humidity percentage fluctuates between 91.5% and 99.9%. Initially, there is a decrease in humidity from 93.2% to 91.5% within the first 50 minutes, followed by a sharp increase to 99.9% at around the 70-minute mark. The humidity then drops slightly and stabilizes before another slight increase towards the end of the period. For temperature, the graph represents the fluctuation of temperature over time, ranging from 20.2°C to 21.9°C. The temperature initially decreases, then increases before decreasing again. For heat index in degrees Celsius over time in minutes. The Heat Index fluctuates between 21.51°C and 22.58°C over a period of 120 minutes.

Table 4.1 Data Collection Table at 3pm to 5pm

Time (min)	Temperature(°C)	Soil Moisture(%)	Humidity(%)	Heat Index(°C)	Lux
10	21.9	43.29	93.2	22.58	467.17
20	21.5	41.67	93.5	22.15	512.64
30	21.4	38.65	93.5	22.04	373.14
40	21.2	35.03	92.8	21.8	362.9
50	21.2	32.81	91.5	21.76	278.21
60	21.5	90.91	99.9	22.31	153.98
70	21.6	90.82	99.9	22.42	58.02
80	21.1	89.46	99.9	22.07	42.42
90	21.2	88.33	99	21.96	49.47
100	20.8	88.66	98.6	21.51	37.98
110	21.1	89.22	97	21.8	37.79
120	20.9	85.19	99.9	21.65	37.14

4.2.2 Wet to Dry Soil Condition

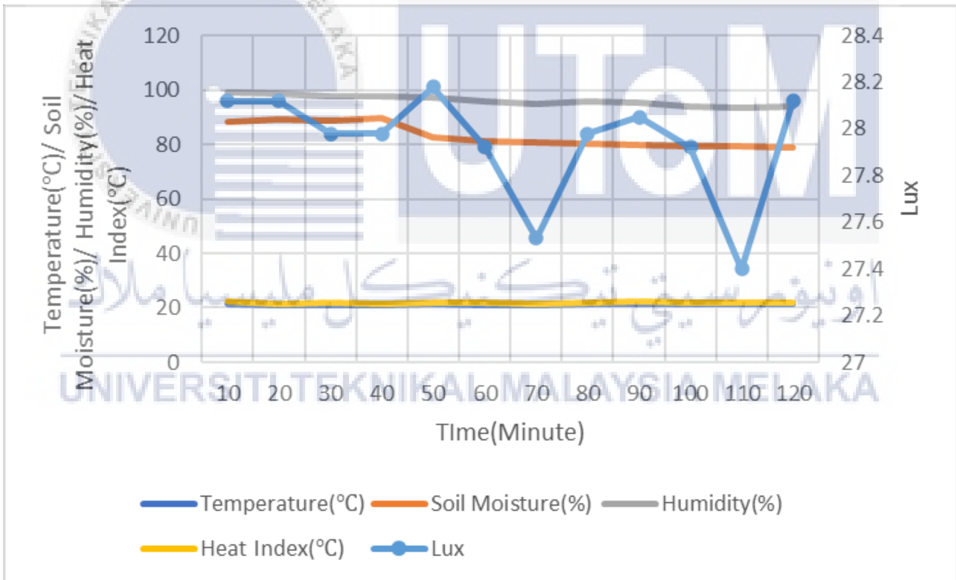


Figure 4.2 Wet to Dry Soil Condition

Based on figure 4.2, show overall result after watering that has been collected from the data logger, data is taken at 5 pm to 7 pm.

For Lux over time, measured in minutes. The Lux value starts at around 28.4, decreases to a low point of 27.4 around the 70-minute mark, and then increases again to 28.4 at the end of the period shown (120 minutes). Low Lux readings around 20 are more associated with cloudy weather conditions which cause light intensity to decrease.

For soil moisture over time. It starts at a higher moisture level of 88.25% and gradually decreases to 78.79% over a period of 120 minutes. The graph indicates that as time progresses, the soil's moisture content is reducing.

For humidity over time. The graph indicates a general decline in humidity over time, starting at 99.2% at 10 minutes and ending at 93.8% at 120 minutes, with some fluctuations in between.

For temperature over time. The temperature, indicated in degrees Celsius, varies between 20.9°C and 21.6°C over a period of 120 minutes. It shows an initial increase from 20.9°C to 21.6°C in the first 10 minutes, followed by fluctuations around the 21°C mark for the remainder of the time. For heat index in degrees Celsius over a period of time in minutes. The highest point on the graph is 22.41°C at 10 minutes, and the lowest point is 21.50°C around 40 minutes. The graph fluctuates before ending at 21.82°C at 120 minutes.

As a result, the system working properly as expected. The plant is in good health. Moreover, from this graph, the relationship between air temperature and relative humidity, the relationship between sunlight illumination and relative humidity and the relationship between sunlight illumination and heat index can be obtain from the analysis from data logger.

Table 4.2 Data Collection Table at 5pm to 7pm

Time (min)	Temperature(°C)	Soil Moisture(%)	Humidity(%)	Heat Index(°C)	Lux
10	21.6	88.25	99.2	22.41	28.12
20	20.9	89.06	98.7	21.62	28.12
30	21.1	88.9	97.6	21.81	27.98
40	20.9	89.79	97.5	21.59	27.98
50	21.2	82.73	97.3	21.92	28.18
60	21.1	81.18	95.7	21.76	27.92
70	20.9	80.56	95	21.53	27.53
80	21.2	80.25	96	21.88	27.98
90	21.6	79.63	95.4	22.31	28.05
100	21.4	79.17	93.9	22.05	27.92
110	21.2	79.32	93.2	21.81	27.4
120	21.2	78.79	93.8	21.82	28.12

4.2.3 Solar Irradiance Levels with Battery Storage

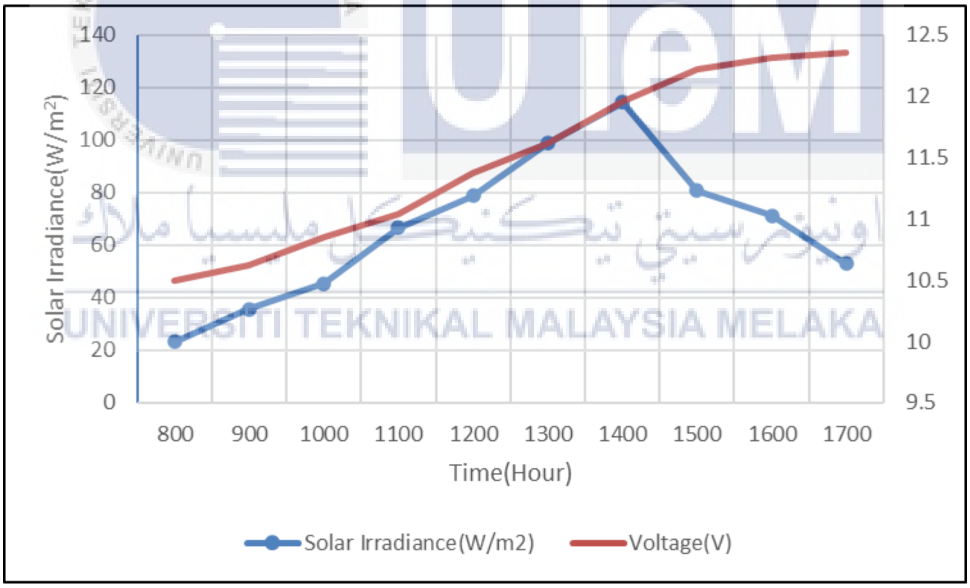


Figure 4.3 Solar Irradiance Levels with Battery Storage

Based on figure 4.3, The solar irradiance measured in Watts per square meter (W/m²) over a period of time in minutes. The solar irradiance increases from 23.34 W/m² at 800 minutes to a peak of 114.56 W/m² at around 1300 minutes, after which it decreases to 53 W/m² by 1700 minutes. The increase and decrease in solar irradiance could be attributed to the sun's position throughout the day, with higher values occurring when the sun is at its zenith and lower values during the early morning and late afternoon.

Solar Irradiance Levels increase, the capacity of Battery Storage increase. However, as daylight diminishes and the system approaches nighttime, there is a notable deceleration in the rate of battery replenishment. This phenomenon is intrinsic to solar energy systems and is attributed to the decreasing solar irradiance during the late afternoon and evening, limiting the generation of electricity by solar panels.

Solar irradiance levels, when combined with battery storage, represent a sustainable and reliable energy solution. Solar irradiance refers to the power per unit area received from the sun in the form of electromagnetic radiation. When harnessed through solar panels, this energy can be stored in batteries for later use, addressing the intermittency of sunlight.

The integration of battery storage addresses one of the key challenges of solar power, its dependency on daylight. During periods of ample sunlight, excess energy generated by solar panels is stored in batteries. This stored energy can then be tapped into during periods of low or no sunlight, ensuring a continuous and reliable power supply.

Table 4.3 T Data Collection Table for Solar Irradiance Levels and Battery Storage

Time(Hour)	Solar Irradiance(W/M2)	Voltage(V)
800	23.34	10.5
900	35.68	10.62
1000	45.45	10.85
1100	66.67	11.04
1200	78.9	11.38
1300	98.78	11.62
1400	114.56	11.96
1500	80.87	12.22
1600	71.23	12.32
1700	53	12.36

4.3 Relationship Between Soil Moisture and Relative Humidity

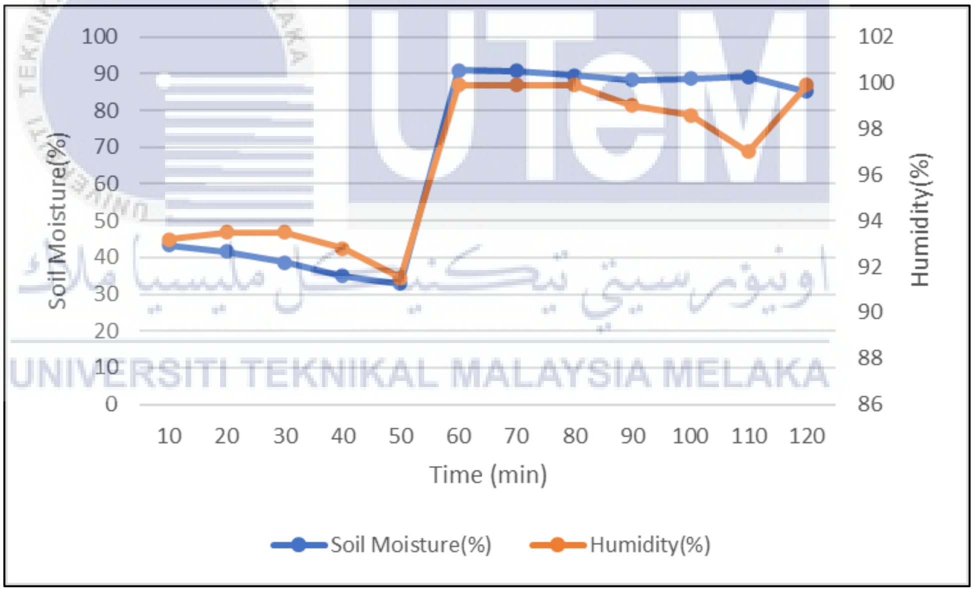


Figure 4.4 Relationship Between Soil Moisture and Humidity

Based on figure 4.4, soil moinsture decrease the relative humidity will decrease and the other way around. When the soil becomes drier and loses moisture, it releases less water vapor into the air. As a result, the air's relative humidity decreases. Similarly, dry soil contributes less moisture to the air, making it feel less humid.

4.4 Relationship Between Air Temperature and Relative Humidity

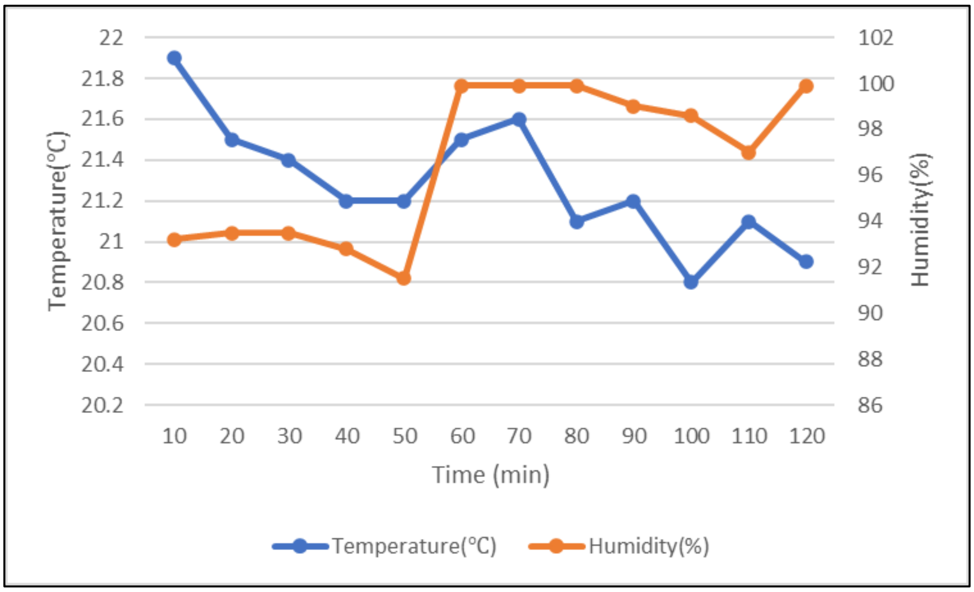


Figure 4.5 Relationship Between Temperature and Humidity

Based on figure 4.5, for the first minute to 100 minute, the graph shows air temperature decrease the relative humidity will decrease and the other way around. when the air gets warmer, it can hold more moisture. So, if the temperature rises, the air has the capacity to carry more water vapor, and as a consequence, the relative humidity goes up. It's akin to a larger sponge being able to absorb more water. In this case, warmer air can contain more moisture, making it feel more humid.

While, after 100 minutes, the graph shows shows air temperature increase the relative humidity will decrease. when the temperature rises, the air can hold more moisture. So, if it gets warmer, the air has the capacity to carry more water vapor, and the relative humidity increases.

4.5 Relationship Between Sunlight Illumination and Relative Humidity

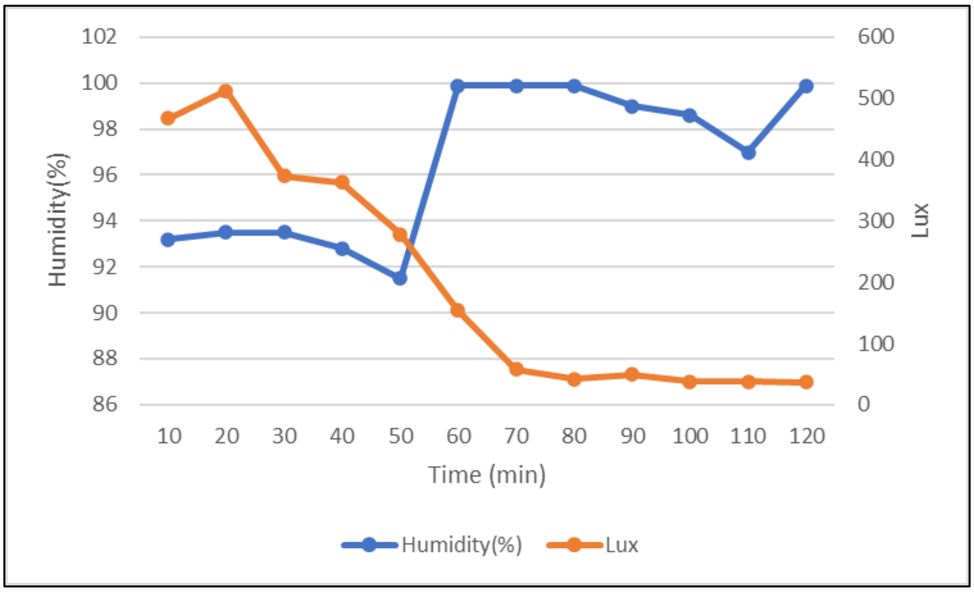


Figure 4.6 Relationship Between Lux and Humidity

Based on figure 4.6, during the first 50 minutes, the sunlight illumination increase the relative humidity of air will decrease. This condition causes when the sunlight decreases, the air has less energy to warm up. Warmer air can hold more moisture, so if there's less sunlight to warm the air, it tends to hold less moisture, and the relative humidity drops. Think of it like a cooler day where the air can't hold as much water vapor, making it feel less humid.

After 50 minutes later, when sunlight decreases, the air has less warmth. Colder air can't hold as much moisture, so if there's less sunlight to warm up the air, it tends to retain more moisture, and the relative humidity goes up. Picture a cooler day where the air can hold onto more water vapor, making it feel more humid.

4.6 Relationship Between Sunlight Illumination and Heat Index.

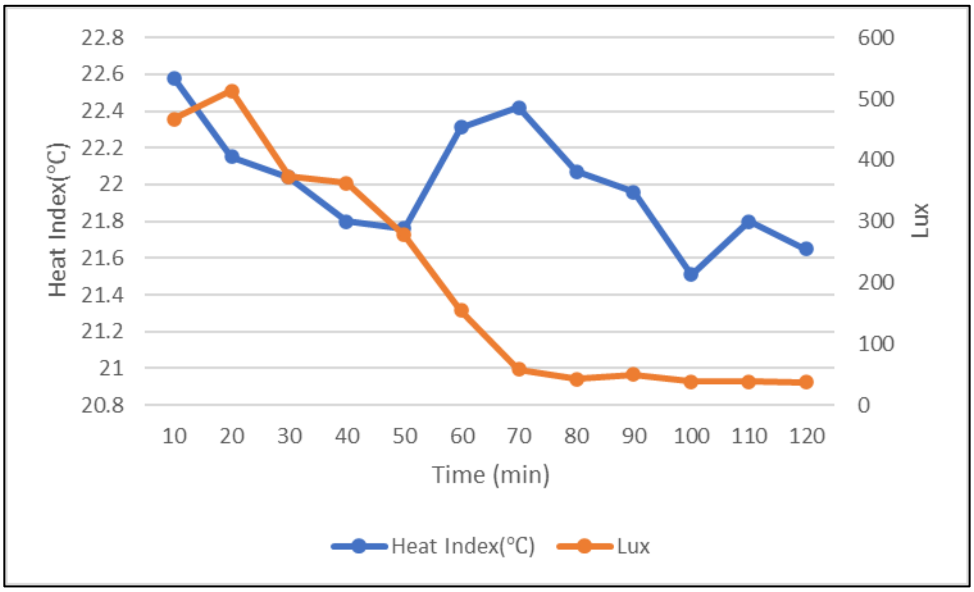


Figure 4.7 Relationship Between Lux and Heat Index

Based on graph 4.7, during the first 50 minutes, the sunlight illumination decrease the heat index will also decrease. This is because the sunlight provides heat energy. Hence the heat index will also increase. Heat index or humiture is a combination of air temperature and relative humidity to measure how it feel when relative humidity is factored by actual air temperature.

After 50 minutes later, the heat index increase but the sunlight illumination still decrease. This happens along with high temperatures, the combination can make it feel hotter than it actually is. The Heat Index tends to increase in such conditions, making it feel warmer, even if the thermometer doesn't show a significant rise in temperature. It's like being in the shade on a hot day, it might not be as bright, but it can still feel quite warm due to the combination of temperature and reduced.

Relative humidity / Temperature	80 °F (27 °C)	82 °F (28 °C)	84 °F (29 °C)	86 °F (30 °C)	88 °F (31 °C)	90 °F (32 °C)	92 °F (33 °C)	94 °F (34 °C)	96 °F (36 °C)	98 °F (37 °C)	100 °F (38 °C)	102 °F (39 °C)	104 °F (40 °C)	106 °F (41 °C)	108 °F (42 °C)	110 °F (43 °C)
40%	80 °F (27 °C)	81 °F (27 °C)	83 °F (28 °C)	85 °F (29 °C)	88 °F (31 °C)	91 °F (33 °C)	94 °F (34 °C)	97 °F (36 °C)	101 °F (38 °C)	105 °F (41 °C)	109 °F (43 °C)	114 °F (46 °C)	119 °F (48 °C)	124 °F (51 °C)	130 °F (54 °C)	136 °F (58 °C)
45%	80 °F (27 °C)	82 °F (28 °C)	84 °F (29 °C)	87 °F (31 °C)	89 °F (32 °C)	93 °F (34 °C)	96 °F (36 °C)	100 °F (38 °C)	104 °F (40 °C)	109 °F (43 °C)	114 °F (46 °C)	119 °F (48 °C)	124 °F (51 °C)	130 °F (54 °C)	137 °F (58 °C)	
50%	81 °F (27 °C)	83 °F (28 °C)	85 °F (29 °C)	88 °F (31 °C)	91 °F (33 °C)	95 °F (35 °C)	99 °F (37 °C)	103 °F (39 °C)	108 °F (42 °C)	113 °F (45 °C)	118 °F (48 °C)	124 °F (51 °C)	131 °F (55 °C)	137 °F (58 °C)		
55%	81 °F (27 °C)	84 °F (29 °C)	86 °F (30 °C)	89 °F (32 °C)	93 °F (34 °C)	97 °F (36 °C)	101 °F (38 °C)	106 °F (41 °C)	112 °F (44 °C)	117 °F (47 °C)	124 °F (51 °C)	130 °F (54 °C)	137 °F (58 °C)			
60%	82 °F (28 °C)	84 °F (29 °C)	88 °F (31 °C)	91 °F (33 °C)	95 °F (35 °C)	100 °F (38 °C)	105 °F (41 °C)	110 °F (43 °C)	116 °F (47 °C)	123 °F (51 °C)	129 °F (54 °C)	137 °F (58 °C)				
65%	82 °F (28 °C)	85 °F (29 °C)	89 °F (32 °C)	93 °F (34 °C)	98 °F (37 °C)	103 °F (39 °C)	108 °F (42 °C)	114 °F (46 °C)	121 °F (49 °C)	128 °F (53 °C)	136 °F (58 °C)					
70%	83 °F (28 °C)	86 °F (30 °C)	90 °F (32 °C)	95 °F (35 °C)	100 °F (38 °C)	105 °F (41 °C)	112 °F (44 °C)	119 °F (48 °C)	126 °F (52 °C)	134 °F (57 °C)						
75%	84 °F (29 °C)	88 °F (31 °C)	92 °F (33 °C)	97 °F (36 °C)	103 °F (39 °C)	109 °F (43 °C)	116 °F (47 °C)	124 °F (51 °C)	132 °F (56 °C)							
80%	84 °F (29 °C)	89 °F (32 °C)	94 °F (34 °C)	100 °F (38 °C)	106 °F (41 °C)	113 °F (45 °C)	121 °F (49 °C)	129 °F (54 °C)								
85%	85 °F (29 °C)	90 °F (32 °C)	96 °F (36 °C)	102 °F (39 °C)	110 °F (43 °C)	117 °F (47 °C)	126 °F (52 °C)	135 °F (57 °C)								
90%	86 °F (30 °C)	91 °F (33 °C)	98 °F (37 °C)	105 °F (41 °C)	113 °F (45 °C)	122 °F (50 °C)	131 °F (55 °C)									
95%	86 °F (30 °C)	93 °F (34 °C)	100 °F (38 °C)	108 °F (42 °C)	117 °F (47 °C)	127 °F (53 °C)										
100%	87 °F (31 °C)	95 °F (35 °C)	103 °F (39 °C)	112 °F (44 °C)	121 °F (49 °C)	132 °F (56 °C)										

Key to colors: Caution, Extreme caution, Danger, Extreme danger

Figure 4.8 Heat Index Table

Based on figure 4.8, the automated greenhouse will ensure the good condition of heat index for the plant. So that the plant can stay in good health condition to produce their crops.

The higher the temperature and humidity, the more challenging it can be for our bodies to cool down through the evaporation of sweat. The Heat Index Table provides a quick reference to understand how hot it might feel, taking into consideration both temperature and humidity. For example, a temperature of 90°F with high humidity might feel like 100°F or more, making it important to stay aware of how weather conditions can impact our comfort and well-being.

4.7 Summary

Based on this chapter, the relationship that can affect the growth of the plant. These data are crucial to provide understanding on how to keep the plant stay in a good condition. Hence it will be reference to botanist to set their greenhouse in desired condition for the plant that will be planted .

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This section will conclude about this project "Development of Automated Greenhouse System For Plants Powered by Solar Energy". The conclusion from this chapter will summarize all this report. In this chapter, it will discuss about the objective of this project is achieved or not, future recommendation and future improvement for this project.

5.2 Conclusion

In conclusion, greenhouse is a building in which plants are grown. Development of Automated Greenhouse System For Plants Powered by Solar Energy can make environment has to be closely monitored so that plants can grow in the best possible conditions. A plant that grows in an environment where air temperature, air humidity, heat index, soil moisture and sunlight illumination are ideal and continuous will be as strong and healthy as it can possibly be.

The project "Development of Automated Greenhouse System for Plants Powered by Solar Energy" has successfully met its main goals. It has created a greenhouse that can precisely control the environment inside. By using advanced technologies like automated systems powered by solar energy, the project shows promise in transforming how we traditionally manage greenhouses.

The project's second objective, centered around the analysis and monitoring of collected data, has provided valuable insights into both the health of the plants and the functionality of the sensors. The real-time data collection and analysis mechanisms have proven effective in ensuring a responsive and adaptive system that caters to the specific needs of the plants.

A crucial aspect of this project involved minimizing waste and ensuring the sustainable use of resources. By optimizing resource efficiency, particularly in water usage and energy consumption, the automated greenhouse system aligns with sustainable agricultural practices. This not only contributes to environmental conservation but also holds economic benefits for farmers through reduced resource costs.

The successful integration of solar energy harvesting into the greenhouse system aligns with contemporary efforts to transition toward renewable energy sources. The project has demonstrated the feasibility of using solar power to meet the energy demands of the greenhouse, marking a significant step towards environmentally conscious agricultural practices.

Essentially, the "Development of Automated Greenhouse System for Plants Powered by Solar Energy" project stands as a testament to the potential of technology-driven, eco-friendly solutions in agriculture. It offers not only a glimpse into the future of farming practices but also a tangible contribution to the global movement towards sustainable and resilient food production systems.

5.3 Potential for Commercialization

The "Development of Automated Greenhouse System for Plants Powered by Solar Energy" project holds great potential for commercial success. With a focus on sustainable practices, resource efficiency, and the integration of advanced technologies like automated systems and solar energy, the system aligns well with the current trends in agriculture. It offers farmers an opportunity to reduce operational costs, while its adaptability to different crops and scalable nature makes it attractive for a broad market. The positive environmental impact and demonstrated success further enhance its appeal, making it a viable solution for those seeking modern, eco-friendly farming practices.

5.4 Future Recommendation

Looking ahead, here are some suggestions for the "Development of Automated Greenhouse System for Plants Powered by Solar Energy."

i) Stay updated on the latest sensor technologies to ensure accurate data monitoring and control through mobile apps.

ii) Consider making the system compatible with a variety of crops beyond strawberries.

iii) Develop easy-to-use tools for farmers to understand and manage data better.

iv) Work with agricultural research institutions for ongoing improvements.

v) Provide training and support for farmers adopting the system.

vi) Look into cost-effective maintenance solutions and ensure compliance with regional regulations for broader market adoption.

These steps will contribute to the system's long-term success and its positive impact on sustainable agriculture.

REFERENCES

[1] Zhao, C., Zhang, Y., Wang, C., Qiao, X., Hao, R., & Yang, Y. (n.d.). (2018) RESEARCH OF GREENHOUSE EFFICIENT..

[2] Khammayom, N., Maruyama, N., Chaichana, C., & Hirota, M. (2022). Impact of environmental factors on energy balance of greenhouse for strawberry cultivation. Case Studies in Thermal Engineering, 33. https://doi.org/10.1016/j.csite.2022.101945.

[3] Wardhani, R. N., & Khodijah, W. (2021). Pemodelan Simulasi Sistem Kontrol Kelembaban Tanah Berbasis Fuzzy Logic pada Automatic Greenhouse. Prosiding Seminar Nasional Teknik Elektro, 6, 35–42..

[4] Jianlun, W., Shuting, W., Jianshu, C., Hao, L., & Dongbo, X. (2019). IFIP AICT 419 - Research on Automatic Irrigation Algorithm of Strawberry Greenhouse Based on PLC.

[5] Tong, X., Sun, Z., Sigrimis, N., & Li, T. (2018). Energy sustainability performance of a sliding cover solar greenhouse: Solar energy capture aspects. Biosystems Engineering, 176, 88–102. https://doi.org/10.1016/j.biosystemseng.2018.10.008.

[6] Rahman, H. A. (2018). CLIMATE CHANGE SCENARIOS IN MALAYSIA: ENGAGING THE PUBLIC. International Journal of Malay-Nusantara Studies, 1(2)..

[7] Viraktamath, S. v, Hegadekatte, S. D., Achari, S. M., & Khawast, S. Y. (2015). AUTOMATIC GREENHOUSE MONITORING AND CONTROLLING SYSTEM USING PLC..

[8] Nemali, K. (2022). History of Controlled Environment Horticulture: Greenhouses. HortScience, 57(2), 239–246. https://doi.org/10.21273/HORTSCI16160-21.

[9] Siddiqui, M. F., Ur Rehman Khan, A., Kanwal, N., Mehdi, H., Noor, A., & Khan, M. A. (2018). Automation and monitoring of greenhouse. 2017 International Conference on Information and Communication Technologies, ICICT 2017, 2017-December, 197–201. https://d.

[10] R, M. S., Yalamalli, V. D., Numan S, S. U., Gowda R, H. K., & D, R. M. (2022). GREENHOUSE MONITORING AND AUTOMATION SYSTEM. International Research Journal of Engineering and Technology. www.irjet.net.

[11] Tekade, R., Kasturkar, V., Londhe, G., & Dhonde, P. S. B. (2021). CONTROLLED ENVIRONMENT STRAWBERRY PLANT GROWING SYSTEM (Vol. 8). JETIR. www.jetir.org.

[12] Kaushalya Madhavi, B. G., Khan, F., Bhujel, A., Jaihuni, M., Kim, N. E., Moon, B. E., & Kim, H. T. (2021). Influence of different growing media on the growth and development of strawberry plants. Heliyon, 7(6). https://doi.org/10.1016/j.heliyon.2021.e0717.

[13] Juan Carlos, A. D., Estrada, L. R., Cesar Augusto, C. R., Paola Patricia, A. C., Marlon Alberto, P. M., Ramón Enrique, R. G., Roberto César, M. O., David Alfredo, O. G., & Carlos Andrés, C. M. (2020). Monitoring system of environmental variables for a str.

[14] Hamad, I. H., Chouchaine, A., & Bouzaouache, H. (2021). A Takagi-Sugeno Fuzzy Model for Greenhouse Climate. In Technology & Applied Science Research (Vol. 11, Issue 4). www.etasr.com.

[15] Kim, K. H. (2013). Greenhouse Control with PV System. In International Journal of Advanced Culture Technology (Vol. 1, Issue 1)..

[16] Juan Carlos, A. D., Estrada, L. R., Cesar Augusto, C. R., Paola Patricia, A. C., Marlon Alberto, P. M., Ramón Enrique, R. G., Roberto César, M. O., David Alfredo, O. G., & Carlos Andrés, C. M. (2020). Monitoring system of environmental variables for a str.

APPENDICES

Appendix A Gantt Chart

PROJECT PLANNING PSM 1														
	2023													
PROJECT ACTIVITY / FYP	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Proposal Project	B													
Decide Project Title	D													
Write a synopsis of our title	P													
Research for the paper related to the title														
CHAPTER 1 DRAFT	B													
Write a objective, problem statement, and scope of the project.	R													
Meet the Supervisor and discuss Chapter 1.	I													
Complete Chapter 1.	E													
CHAPTER 2 DRAFT	F													
Research Article and Journal about the Project.	I													
Write a draft of Chapter 2.	N													
Meet the Supervisor and discuss Chapter 2.	G													
Complete Chapter 2.														
CHAPTER 3 DRAFT	P													
Research for hardware and software	S													
Search for the software and component used.	M													
Sketch the circuit and prototype.	1													
Simulation Project.														
Meet the Supervisor and discuss Chapter 3.	2													
Complete Chapter 3.	2													
SLIDE PRESENTATION	/													
Complete a full report for PSM 1.	2													
Complete Slide Presentation.	3													

PROJECT PLANNING PSM 2														
	2023													
PROJECT ACTIVITY / FYP	01	02	03	04	05	06	07	08	09	10	11	12	13	14
CHAPTER 4 DRAFT	B													
Circuit Design	D													
Buy Item	P													
Software Analysis														
Hardware Analysis	B													
Project Degisn	R													
Sensor Analysis	I													
Troubleshoot	E													
Data collection 1	F													
Data Anlysis 1	I													
Builds Hardware	N													
Testing Solar Panel	G													
Data Collection 2														
Data Anlysis 2	P													
Hardware Testing	S													
Complete Chapter 4	M													
CHAPTER 4 DRAFT	2													
Draft Chapter 5														
Poster	2													
Complete Chapter 5	3													
SLIDE PRESENTATION	/													
Complete a full report for PSM 2	2													
Complete Slide Presentation	4													

Appendix B Programming Code

```
//Libraries
#include "DHT.h"
#include <SPI.h>
#include <SD.h>
#include <Wire.h>

#define DHTTYPE DHT22
#define ECHO_TO_SERIAL 1
#define LOG_INTERVAL 360000

const int soilMoisturePin = A0;
const int sunlightPin = A1;
const int dhtPin = 2;
const int chipSelect = 4;
const int solenoidPin =7;
const int ac2 = 10;
const int ac = 9;
const int LED = 8;
const int wateringtime = 600000;

DHT dht(dhtPin,DHTTYPE);

float soilMoistureRaw = 0;
float soilmoistureactual = 0;
float soilMoisture = 0;
float humidity = 0;
float airTemperature = 0;
float heatIndex = 0;
float sunlight = 0;
bool watering = false;
bool wateredToday = false;
```

```
float lux=0.00;
float ADC_value=0.0048828125;

File dataFile;

void setup() // put your setup code here, to run once:
{
Serial.begin(9600); //baud rate
Serial.println("Initializing SD card...");
pinMode(solenoidPin, OUTPUT);
pinMode(ac, OUTPUT);
pinMode(ac2, OUTPUT);
pinMode(LED, OUTPUT);
digitalWrite(solenoidPin,HIGH);
digitalWrite(ac,HIGH);
digitalWrite(ac2,HIGH);
digitalWrite(LED,HIGH);

dht.begin();

 /*Serial.print("Initializing SD card...");

  // see if the card is present and can be initialized:
  if (!SD.begin(chipSelect)) {
    Serial.println("Card failed, or not present");
    // don't do anything more:
    return;
  }
  Serial.println("card initialized.");
  File dataFile = SD.open("datalog.csv", FILE_WRITE);
  dataFile.print("Air Temp (C),Soil Moisture Content (%),Relative Humidity (%),Heat
Index (C),Sunlight Illumination (lux),Watering?");   //HEADER
```

```
  Serial.println("Air Temp (C),Soil Moisture Content (%),Relative Humidity (%),Heat
Index (C),Sunlight Illumination (lux),Watering?");
  dataFile.close();*/

}

void loop() // put your main code here, to run repeatedly:
{

  soilMoistureRaw = analogRead(soilMoisturePin)*(3.3/1024);
  delay(20);

  if (soilMoistureRaw < 1.1)
  {
    soilMoisture = (10 * soilMoistureRaw) - 1;
  }
  else if (soilMoistureRaw < 1.3)
  {
    soilMoisture = (25 * soilMoistureRaw) - 17.5;
  }
  else if (soilMoistureRaw < 1.82)
  {
    soilMoisture = (48.08 * soilMoistureRaw) - 47.5;
  }
  else if (soilMoistureRaw < 2.2)
  {
    soilMoisture = (26.32 * soilMoistureRaw) - 7.89;
  }
  else
  {
    soilMoisture = (62.5 * soilMoistureRaw) - 87.5;
  }
  soilmoistureactual = 100- soilMoisture;
```

```
  humidity = dht.readHumidity();
  delay(20);

  airTemperature = dht.readTemperature();
  delay(20);

  heatIndex = dht.computeHeatIndex(airTemperature,humidity,false);

  lux = (250.000000/(ADC_value*analogRead(sunlightPin)))-50.000000;
  delay(20);



/*File dataFile = SD.open("datalog.csv", FILE_WRITE);*/

  /*// if the file is available, write to it:
  if (dataFile)
  {

    //Log variables

  dataFile.print(airTemperature);
  dataFile.print(",");
  dataFile.print(soilmoistureactual);
  dataFile.print(",");
  dataFile.print(humidity);
  dataFile.print(",");
  dataFile.print(heatIndex);
  dataFile.print(",");
  dataFile.print(lux);
  dataFile.print(",");
  dataFile.print("\n");

  dataFile.close();
```

```
  // print to the serial port too:

 Serial.print(airTemperature);
 Serial.print(",");
 Serial.print(soilmoistureactual);
 Serial.print(",");
 Serial.print(humidity);
 Serial.print(",");
 Serial.print(heatIndex);
 Serial.print(",");
 Serial.print(lux);
 Serial.print(",");
 Serial.print("\n");
 }
 else
 {
  dataFile.print("FALSE");
#if ECHO_TO_SERIAL
  Serial.print("FALSE");
#endif
 }*/

 Serial.print(airTemperature);
 Serial.print("\t");
 Serial.print(soilmoistureactual);
 Serial.print("\t");
 Serial.print(humidity);
 Serial.print("\t");
 Serial.print(heatIndex);
 Serial.print("\t");
 Serial.print(lux);
 Serial.print("\t");
```

```
if (soilmoistureactual < 30)
{
 //water the garden
 digitalWrite(solenoidPin, LOW);
 Serial.print("W.Pump ON\t");
 delay(5000);
 digitalWrite(solenoidPin, HIGH);
 //delay(30000);
 //Serial.print("\n");
 //Serial.print("\t\t\t\t\t");
 //Serial.print("W.Pump OFF   ");


 //record that we're watering
 dataFile.print("TRUE");


 //Serial.print("TRUE");


}
if (soilmoistureactual >= 30)
{
 //water the garden
 digitalWrite(solenoidPin, HIGH);
 Serial.print("W.Pump OFF   ");
  }
if(airTemperature > 20)
{
 digitalWrite(ac, LOW);
 digitalWrite(ac2, LOW);
 Serial.print("AC ON   ");
}
if(airTemperature <= 20)
{
 digitalWrite(ac, HIGH);
```

```
  digitalWrite(ac2, HIGH);
  Serial.print("AC OFF   ");
 }

 if(lux < 45)
 {
  digitalWrite(LED, LOW);
  Serial.print("LED ON   ");
 }
  if(lux > 45)
 {
  digitalWrite(LED, HIGH);
  Serial.print("LED OFF   ");
 }
 Serial.print("\n");
 delay(59470);
}
```