Faculty of Electrical Technology and Engineering

DESIGN AND IMPLEMENTATIONS OF AN IOT BASED PLANT MONITORING AND IRRIGATION SYSTEM USING SOLAR ENERGY

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**Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics)
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DESIGN AND IMPLEMENTATIONS OF AN IOT BASED PLANT MONITORING AND IRRIGATION SYSTEM USING SOLAR ENERGY

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A project report submitted
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DEDICATION

I would like to express my gratitude to both of my parents, Md Rozani bin Hussin and Fatimah binti Arifin, for their support and encouragement during the completion of my senior Final Year Project. My parents always made sure to celebrate the little victories and give me words of encouragement whenever I accomplished something new. In addition to that, they made a pleasant space for me to work in so that I could generate concepts and find motivation to finish my duties

ABSTRACT

This project aims to develop an Internet of Things (IoT) based plant monitoring and irrigation system powered by solar energy. The system will enable the efficient management of plants by continuously monitoring their environmental conditions such as soil moisture, temperature and humidity and transmit the collected data to the Blynk platform. The Blynk application can then display this data in the form of interactive widget, providing users with insights into their plants' health and growth. By employing IoT technology, the system will provide real-time data to users, allowing them to remotely monitor and control the irrigation process. The integration of solar energy will ensure a sustainable and environmentally friendly power source for the system, reducing dependence on conventional electricity. Overall, this project offers an innovative solution for plant care, enhancing productivity and conservation through the implementation of IoT and solar energy technologies. The performance of this system can be measured by conducting experiments. First, there is the solar charging test. Next, an assessment of the accuracy of temperature and humidity sensors was performed, achieving a temperature accuracy of 98% and a humidity sensor accuracy of 95%. Additionally, the soil moisture sensor for the irrigation system was tested, resulting in a measurement accuracy error of only about 2% to 3% for the water level sensor. A comparison of plant growth was also conducted, revealing that the plants exhibited slightly better growth, approximately 7% to 10%, compared to traditional farming.

ABSTRAK

Projek ini bertujuan untuk membangunkan sistem pemantauan dan penyiraman tumbuhan berdasarkan Internet of Things (IoT) yang dikuasakan oleh tenaga solar. Sistem ini akan membolehkan pengurusan tumbuhan yang cekap dengan memantau secara berterusan keadaan persekitaran mereka seperti kelembapan tanah, suhu, dan kelembapan dan menghantar data yang dikumpulkan ke platform Blynk. Aplikasi Blynk kemudian dapat memaparkan data ini dalam bentuk widget, memberi pemilik dengan pandangan terperinci tentang kesihatan dan pertumbuhan tumbuhan mereka. Dengan menggunakan teknologi IoT, sistem ini akan menyediakan data secara langsung kepada pengguna, membolehkan mereka memantau dan mengawal proses penyiraman secara jauh. Integrasi tenaga solar pula akan memastikan sumber tenaga yang mampan dan mesra alam untuk sistem ini, mengurangkan bergantung kepada tenaga elektrik konvensional. Secara keseluruhannya, projek ini menawarkan penyelesaian inovatif untuk penjagaan tumbuhan, meningkatkan produktiviti dan pemuliharaan melalui pelaksanaan teknologi IoT dan tenaga solar. Prestasi sistem ini boleh diukur melalui ujikaji eksperimen. Pertama, terdapat pengujian pengecasan solar. Kemudian, penilaian ketepatan sensor suhu dan sensor kelembapan telah dijalankan, ketepatan sensor suhu sebanyak 98% dan ketepatan sensor kelembapan sebanyak 95%. Selain itu, sensor kelembapan tanah untuk sistem pengairan juga diuji,manakala sensor paras air pula menghasilkan ralat ketepatan pengukuran hanya kira-kira 2% hingga 3%. Perbandingan pertumbuhan tanaman juga dijalankan, mendedahkan bahawa tanaman menunjukkan pertumbuhan yang sedikit lebih baik, kira-kira 7% hingga 10%, berbanding pertanian tradisional.

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LIST OF ABBREVIATIONS

V - Voltage
cm - Centimeter
C - Current
IoT - The Internet of Things (IoT)

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CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, the Internet of Things (IoT) has revolutionized various industries with its vast range of applications. One field where IoT has gained significant popularity and demonstrated its immense potential is agriculture. The integration of IoT into agricultural practices has led to the development of smart and efficient farming techniques, improving productivity, resource management, and sustainability. Figure 1.1 shows the Agriculture Revolution.

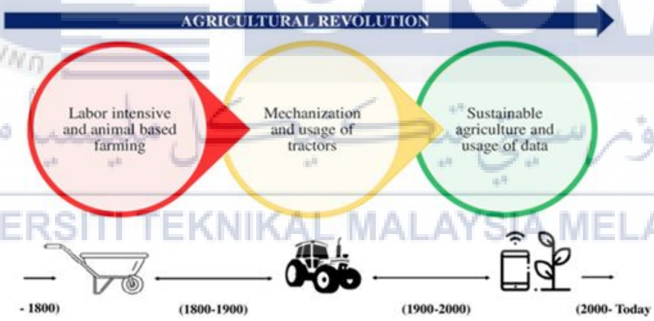


Figure 1.1 Agriculture Revolution Diagram

Traditionally, agriculture heavily relied on manual labor and guesswork, making it challenging to achieve optimal plant growth and maximize crop yield. Farmers had to manually monitor environmental conditions, such as soil moisture, temperature, humidity, and light levels. This lack of real-time data often resulted in over-watering or under-watering, inadequate nutrient supply, and inefficient resource utilization. However, with the advent of IoT, farmers now have access to advanced plant monitoring and irrigation systems that utilize interconnected devices to gather data and provide actionable insights. By deploying various sensors and actuators throughout the farm, these IoT systems can collect and transmit valuable information in real-time.

For instance, soil moisture sensors can measure the exact water content in the soil, while temperature and humidity sensors monitor the surrounding environmental conditions. The data collected by these IoT devices is sent to a central hub or cloud-based platform, where it is analyzed using sophisticated algorithms and machine learning models, for better understanding can refer to Figure 1.2 below. By leveraging historical and real-time data, these systems can generate accurate and customized recommendations for irrigation, fertilization, and overall plant management. This information is then relayed to the farmers through user-friendly interfaces, such as mobile applications or web-based dashboards.

Figure 1.2 IoT Smartfarm Data Collection

Solar-powered IoT systems offer increased autonomy and resilience, as they can operate even in remote or off-grid areas. The energy captured by PV panels can be stored in batteries, ensuring a continuous power supply for the IoT devices, and maintaining data collection and transmission even during cloudy days or power outages. In addition to optimizing irrigation, IoT-based systems in agriculture can provide valuable insights for precision farming [1]. By analyzing data from various sensors, farmers can identify patterns, detect anomalies, and make data-driven decisions to improve crop yield, quality, and disease management.

For instance, the data collected by IoT devices can help identify early signs of plant stress, nutrient deficiencies, or pest infestations, enabling timely intervention and reducing crop losses [2]. Moreover, the integration of IoT into agriculture facilitates remote monitoring and control. Farmers can access real-time data and control the irrigation system or adjust environmental parameters from anywhere, using their smartphones or other connected devices. This level of flexibility and accessibility empowers farmers to make informed decisions promptly, optimizing resource allocation and mitigating risks.

In conclusion, the implementation of IoT-based plant monitoring and irrigation systems powered by solar energy presents a game-changing solution for sustainable and efficient agriculture. By leveraging real-time data collection, analysis, and intelligent decision-making, these systems revolutionize traditional farming practices. They enhance water conservation, minimize energy consumption, improve crop productivity, and contribute to overall environmental sustainability. With the continuous advancements in IoT technologies, the future of agriculture holds tremendous potential for increased efficiency, reduced resource wastage, and improved global food security.

1.2 Problem Statement

With the rapid growth of the world's population, food production has become a critical issue. To meet the increasing demand for food, farmers need to maximize their crop yield while minimizing their water usage. However, traditional irrigation methods are inefficient and can waste significant amounts of water. Additionally, farmers face challenges such as unpredictable weather conditions, limited availability of energy sources, and limited access to real-time crop monitoring. To address these challenges, an IoT-based plant monitoring and irrigation system with solar energy can be designed. The system will use IoT sensors to monitor the soil moisture, temperature, and humidity levels, as well as the light intensity. This data will be collected and analyzed by a cloud-based software system, which will provide real-time updates on the crop's health and growth. The system will also incorporate a solar-powered irrigation system, which will deliver the right amount of water to the plants at the right time. The solar panels will power the irrigation system, making it a sustainable and cost-effective solution. The goal of this project is to design an IoT-based plant monitoring and irrigation system with solar energy that can help farmers optimize their crop yields while reducing water usage and energy costs.

1.3 Project Objective

Project objectives are as follows:

a) To design and develop an IoT based plant monitoring and irrigation system using NodeMcu ESP32.

b) To develop a system with real-time information on the soil moisture level and surrounding condition in terms of humidity and temperature.

c) To analyze the performance of IoT based plant monitoring and irrigation systems.

1.4 Scope of Project

The scope of this project are as follows:

a) Using NodeMcu ESP32 microcontroller as a brain to control all the components and sensors in this project.

b) A solar energy with powerbank module will be a power supply for NodeMcu ESP32 microcontroller.

c) A mobile application has been designed to effectively present and monitor data obtained from a NodeMcu ESP32 device.

d) A mobile application can control waterpump when needed.

e) The NodeMcu ESP32 device and the mobile application established a communication link utilizing a Wi-Fi connection.

f) A humidity and temperature sensor will monitor surrounding conditions.

g) Ultrasonic sensor will monitor the water level of the water tank.

h) A soil moisture sensor is used to monitor moisture level of the crop.

i) When the moisture level of the crop is lower than it should be, a water pump is utilized to transfer water to the crops.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides a detailed literature analysis on the design and implementation of a plant monitoring and irrigation system driven by solar energy that is based on the Internet of Things (IoT). The literature study covers a variety of topics, including the development and influence of IoT in agriculture, the optimization of irrigation systems, the incorporation of solar power into agricultural practices, and current trends in smart agriculture as well as future possibilities. The study also takes a look at prior research projects as well as IoT-based agricultural systems that are now in use, noting the benefits, drawbacks, and opportunities for enhancements associated with each.

The Internet of Things (IoT) has brought about huge revolutions in many different industries, one of the key beneficiaries of which being agriculture. The Internet of Things has made it possible to link equipment and systems so that data can be gathered, sent, and analyzed. This has led to the development of more modern agricultural practices. As a result, a significant portion of the evaluation of the relevant literature is devoted to gaining a grasp of the Internet of Things' (IoT) effect on agriculture, as well as its prospective advantages and its ability to change traditional agricultural practices into intelligent farming procedures.

Utilizing sensor technology, the use of the Internet of Things (IoT) in agriculture, also known as smart farming or precision agriculture, collects vital data on a variety of environmental factors, such as the amount of soil moisture, temperature, humidity, and light intensity. The use of complex algorithms and machine learning models to the examination of this data produces actionable insights that can be applied to irrigation, fertilization, and the general management of agricultural production. This review investigates prior research and actual systems that make use of IoT-based technologies, analyzing their research approaches, conclusions, and the implications such findings have for the direction of future study.

The management of irrigation is an essential part of environmentally friendly agriculture, and whether there is an adequate amount of water available or not may have a significant impact on crop health and productivity. Due to a lack of real-time data on soil moisture and climatic conditions, traditional methods of irrigation often result in significant amounts of wasted water as well as increased consumption of electricity. In this review of the relevant literature, we examine research works that have concentrated on Internet of Things (IoT)-based irrigation systems and their potential to improve both water and energy efficiency. In this chapter, we also cover the many different sensor technologies that are used for monitoring soil moisture and the role that these technologies play in maximizing the effectiveness of irrigation practices.

The power supply is one more component that plays a vital role in the overall design of an Internet of Things-based plant monitoring and irrigation system. The literature study analyses the practicability and advantages of incorporating solar energy into these systems, which provides an environmentally friendly answer to the problem of meeting energy needs. A sustainable and clean form of energy that may power Internet of Things devices and systems is solar power, which is harvested by photovoltaic (PV) panels. This kind of energy can make IoT devices and systems more independent and robust, particularly in distant or off-grid places.

The paper also analyses prior research projects that have effectively incorporated solar energy into IoT-based agricultural systems, providing an overview of the design, implementation, and performance results of these systems. In addition, it investigates the various hurdles that may arise in the process of capturing and storing solar energy and indicates potential solutions that may be used to overcome these issues.

The last section of this chapter provides an overview of some of the developing trends in smart agriculture. Some of these trends include the use of artificial intelligence (AI) and machine learning (ML) for data analysis, the use of drone technology for aerial surveillance, and the application of big data in predictive analytics for agricultural purposes. These developments not only indicate the ongoing growth of IoT-based agricultural systems, but they also bring attention to the potential of these technologies to improve agricultural production, environmental sustainability, and global food security.

The purpose of this in-depth literature study is to build a solid theoretical framework that may serve as a platform for guiding the design and execution of an Internet of Things-based plant monitoring and watering system that is powered by solar energy. The review will not only help in knowing the current state-of-the-art in smart agriculture, but it will also give crucial insights into the gaps in existing systems that the proposed project can solve. This is because the review will help in understanding the current state-of-the-art in smart agriculture. In addition to this, it will provide a clear grasp of the possible advantages and problems connected with such systems, which will contribute to decisions that are more informed and effective across the whole of the project.

2.2 Overview of Plant Monitoring and Irrigation System

Throughout the years, there has been a gradual growth of agricultural practices, which has led to the creation of a variety of technologies that optimize farming procedures. In particular, plant monitoring and irrigation systems have gone through substantial alterations as a direct result of the need to reduce water use, increase agricultural output, and satisfy a rising demand for food. This section offers an overview of these systems, beginning with more conventional practices and progressing all the way up to contemporary IoT-based procedures.

2.2.1 Conventional Method for the Monitoring and Irrigation of Plants

Historically, physical labour and practises of observation have been relied on heavily as primary means for carrying out plant monitoring and watering. In the past, farmers relied on their own experience and the information they had gained from living in the area to decide when and how much water to apply to their crops [3]. In order to determine the plants' water needs, they would carefully inspect the plants for observable physical symptoms such as withering leaves. On the other hand, these techniques require a lot of manual labour, are very subjective, and often result in an inefficient use of water, which may either lead to over-irrigation or under-irrigation [4].

Farmers have also made use of simple technology like rain gauges and soil tensiometers to determine the amount of precipitation that has fallen and the moisture content of the soil [5]. Although these technologies do give a degree of impartiality, their use is often limited by their lack of precision and the absence of data that is updated in real time.

2.2.2 Irrigation Systems That are Both Automated and Based on Sensor

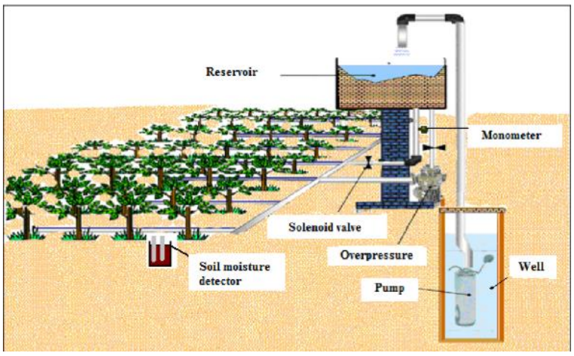


Figure 2.1 Automated irrigation system

The progression of technology ultimately resulted in the creation of irrigation systems that are both automated and reliant on sensors. According to studies such systems generally comprise of soil moisture sensors that automatically begin irrigation when the level of soil moisture falls below a certain threshold. These systems have greatly increased water efficiency in comparison to older approaches, principally by removing the element of guessing and lowering the risk of either over-irrigation or under-irrigation [6].

In spite of the fact that sensor-based irrigation systems have been shown to enhance water efficiency, these systems often have drawbacks due to the fact that they do not integrate with other environmental factors such as temperature and humidity. These variables may have a considerable impact on the amount of water a plant requires, making it imperative that irrigation management take them into account [7].

2.2.3 Irrigation and Plant Monitoring System That are Powered by The Internet of Thing (IoT)

The Internet of Things (IoT) has introduced even more advancements that have further revolutionised the process of plant monitoring and watering. Internet of Things-based systems make use of a network of linked devices, which may include a variety of sensors and actuators, to collect, send, and analyse data in real time [8].

In these systems, sensors for the soil moisture, temperature, humidity, and light are dispersed across the farm in order to capture a wide variety of environmental data. These data are then transported to a central hub or cloud-based platform, where they are analysed using complex algorithms or machine learning models [9].

The IoT system is able to do data analysis and develop exact and individualised irrigation plans, which enable the system to accurately determine when and how much water should be applied to the plants. These technologies lower the amount of water that is wasted, increase the efficiency with which water and energy are used, and promote overall plant health and production [10].

In addition, the data that is gathered by the IoT system may give significant insights into a variety of elements of plant health and development, such as phases of growth, indications of illness, and nutritional shortages. By doing an analysis of this data enables farmers to make educated choices on the management of their crops, hence minimising crop losses and maximising output [11].

2.2.4 IoT Plant Monitoring and Irrigation System That are Powered by Solar Energy

Figure 2.2 Solar powered IoT project

Solar power has emerged as a viable option for supplying the energy needed to run Internet of Things-based plant monitoring and irrigation devices. Solar-powered systems reduce their dependency on electricity generated by fossil fuel generators or the grid by harvesting energy from the sun via the use of photovoltaic (PV) panels [12].

IoT systems that are fueled by solar energy provide enhanced autonomy and resilience, particularly in places that are off-grid or in distant locations. Even on cloudy days or when there is a power outage, the energy that is collected by the PV panels may be stored in batteries, which guarantees a constant power supply for the Internet of Things devices and maintains data collecting and transmission [13].

To summarise, plant monitoring and irrigation systems have seen substantial changes over the course of time, mostly because of developments in technology as well as an increased emphasis on environmentally responsible agricultural practices. The incorporation of the internet of things and solar energy into these systems has resulted in a game-changing solution, which has improved water and energy efficiency, increased agricultural output, and contributed to the general sustainability of the environment.

2.3 Challenges in Traditional Plant Monitoring and Irrigation

Traditional methods of plant monitoring and irrigation, although being essential to the development of agriculture, have been beset by a great deal of difficulty throughout the years. The intensity of the physical labour, the lack of precision, the absence of real-time data, and the lack of regard for the environment have all contributed to a reduction in the effectiveness and productivity of these systems. In the next part, we will investigate these difficulties and explore the consequences that they have for the use of water, the yield of crops, and sustainable agriculture.

2.3.1 Labor-Intensity

The most important aspect of traditional agricultural practices, such as plant monitoring and irrigation, is the involvement of manual labour [14]. Due to the lack of automation, many activities need a large amount of human engagement to be completed. Farmers are required to manually evaluate the moisture levels of the soil, as well as the health of the plants and their rate of growth, and then change the irrigation schedule appropriately.

This labor-intensive strategy often proves to be ineffective, particularly in farming on a big scale, owing to the substantial amounts of time, effort, and expenditures that are required in the process. Because of the substantial dependence on human labour, these methods are also less scalable, which hinders the capacity of farmers to develop their businesses and fulfil the rising demand for food [15].

2.3.2 Imprecision and Use of Guesswork

The inherent imprecision and element of guessing that is included in conventional plant monitoring and watering systems is another significant obstacle that must be overcome. Farmers often rely on their own personal experience as well as visual observations to decide when and how much to water their land [16]. For instance, the presence of symptoms such as wilting or stress on a plant may be an indication that it needs watering. However, owing to the subjective character of such practices and the absence of quantitative data, they often result in either over-irrigation or under-irrigation of the land.

Even when using very simple measuring devices, such as rain gauges or soil tensiometers, the reliability of the results from these approaches is often called into doubt. These tools only offer approximate estimations and do not take into consideration the variation in soil moisture that exists throughout the field in various locations [5]. This results in an unequal distribution of water.

2.3.3 Lack of Data Collected in Real Time

The traditional techniques of irrigation do not offer data in real time, which is very necessary for effective water management. According to past studies, the inability of farmers to access data in real time hinders their capacity to react quickly to shifting climatic circumstances such as an abrupt increase in temperature or a reduction in the amount of rainfall. This delay in reaction may result in incorrect watering, which may have a negative impact on the crops' health as well as their production.

In addition, farmers are unable to efficiently monitor the development and health of their crops if they do not have access to real-time data. It is possible to overlook the early warning signals of plant stress, nutrient deficits, or disease infestations, which may result in large crop losses [17].

2.3.4 Absence of Any Consideration for the Environment

When it comes to irrigation management, traditional irrigation systems sometimes ignore how important it is to take a variety of environmental conditions into consideration, such as temperature, humidity, and the intensity of the light. According to studies, the exclusion of these elements may greatly reduce the effectiveness of water use, since they have a considerable impact on the amount of water that plants need [18].

For example, high temperatures and low humidity levels may both contribute to increased evapotranspiration, which in turn leads to an increase in the amount of water that the crops need. Because traditional irrigation methods only consider the amount of moisture in the soil, they often do not take into consideration the many ways in which the surrounding environment might change. This neglect may lead to either excessive or insufficient watering, both of which can have a negative impact on the crop's health and productivity.

In conclusion, the difficulties that are associated with conventional plant monitoring and irrigation systems highlight the need for agricultural practises that are more technically advanced and driven by data. It is essential to make the shift from conventional to cutting-edge Internet of Things (IoT)-based plant monitoring and irrigation systems in order to keep up with the rising demand for food on a worldwide scale and the increasing emphasis placed on environmentally responsible agricultural practises.

2.4 Internet of Things (IoT) in Agriculture

The use of the Internet of Things (IoT) in agriculture, also known as IoT-based agriculture or smart farming, has emerged as a potentially game-changing strategy to improve agricultural production, efficiency, and long-term sustainability. This strategy is also known as "smart farming." This section offers an overview of IoT introduction, cloud-based solutions and the implementation of IoT in agriculture, including its potential advantages as well as the numerous IoT technologies and devices that are utilized in smart farming practices.

2.4.1 Introduction to Internet of Thing (IoT)

The Internet of Things (IoT) represents a burgeoning technological advancement that holds the potential to revolutionize various aspects of human existence, encompassing both professional and personal spheres. This term denotes a network of tangible entities, commonly referred to as "things," which possess integrated systems comprising connectivity and computational capabilities. Through these attributes, these objects can seamlessly communicate and share data with other devices and systems via the Internet [19].

2.4.2 Internet of Things (IoT) and Cloud-Based Solutions

In today's world, smart and linked things are becoming increasingly common. The major purpose of the Internet of Things (IoT) is to link industrial machinery and create a framework for data-driven decisions to be made without the need for human intervention. Some of the components required to build the IoT include the ESP8266 ESP-01 Wi-Fi module, GSM shield, and Bluetooth module HC-06. MQTT broker, Node-RED, Ubuntu

IoT Cloud, ThingSpeak, and the MIT app are examples of solutions for monitoring IoT elements in real time through the internet network. The key benefit of utilizing these technologies is that much of the programming has already been completed. Existing code for various purposes, such as monitoring interfaces, remote applications, and wireless technologies, can be merged and used for the project as needed. Remote control programs allow you to tell system actuators how to interact with or alter certain parameters. Open-source solutions are frequently selected because they are well-documented, updated on a regular basis, and do not require the involvement of a corporate body to function. Table 2.1 will give a list and information of available software.

Table 2.1Type of software

Software	CloudBased	Database	Source	Accessibility	Description
online Google® spreadsheet	Yes	Free	Open	Application	The Docs suite backs up your data automatically and makes collaboration simple for everyone.
Web Application	Yes	Need to beprepared	Open	Web Browser	• A Web application (Web app) is a piece of software that is hosted on a remote server and distributed through the Internet using a browser interface. Webservices are Web applications, by definition, and many, but not all, websites include Web apps. • Commonly used Web apps includewebmail, online. calculators, and e-commerce shops.
Line Notify	No	Free of charge. But when linking to other web services, there may be features that can only be used with paid accounts, depending onthe service.	Close	LINE Notify's official account	• A Line Notice is an alert from the LINE program, which can send messages tothe feeders' accounts. • The LINE program is a free talking application that is used in this study to notify users, as well as the Mackerel platform, which is a platform for examining servers for GitHub engineering and a web service that can work with IFTTT software. The NodeMCU in this investigation worked by sending notifications to the feeders via the LINE program.

Software	CloudBased	Database	Source	Accessibility	Description
Blynk	Yes	Free	Open	Application	Blynk is an IoT platform for iOS and Android smartphones that allows you to operate Arduino, Raspberry Pi, and NodeMCU from anywhere in the world. This application is used to create a graphical interface or human machine interface by compiling and providing the appropriate address on the available widgets (HMI).
Microsoft excel	Yes	Free	Open	Web browser/ Application	Microsoft Excel is a spreadsheet tool developed by Microsoft for Windows, macOS, Android, and iOS. Visual Basic for Application is a macro programming language that contains calculation and computing tools, graphing tools, pivot tables, and Visual Basic for Applications (VBA). Excel is an application that is part of the Microsoft Office product suite.
Thingspeak	Yes	Free servicefor non-commercialsmall projects	Open	Application	• ThingSpeak is a cloud based IoT analyticsapplication for collecting, visualizing, and analyzing real-time data streams. ThingSpeak allows you to send data from your devices, create real-time visualizations of live data, and set alerts. ThingSpeak Features • Works With: 1. MATLAB® & Simulink® 2. Arduino® 3. Particle devices

2.4.3 Implementation of Internet of Thing (IoT) in Agriculture

The Internet of Things has a broad variety of applications in agriculture, including plant monitoring, irrigation management, animal tracking, crop disease diagnosis, and precision farming, to name a few of these applications. Internet of Things (IoT)-based agricultural systems gather, transmit, and analyse real-time data by using networked devices, sensors, actuators, and data analytics. This enables informed decision-making and accurate management of available resources.

2.4.3.1 Plant Surveillance and Agriculture Production Management

IoT technologies play an important part in plant monitoring and crop management. These technologies enable farmers to continually monitor and analyse a variety of environmental indicators, which is critical for plant monitoring and crop management. Fields are equipped with moisture sensors, temperature sensors, humidity sensors, and light sensors in order to gather data on the soil conditions, ambient temperature, humidity levels, and light intensity. After that, the data is uploaded to various cloud-based systems for further analysis.

According to past studies, Internet of Things (IoT)-based agricultural systems are able to give insights about plant health, development phases, nutrient deficits, and disease outbreaks. These insights may be obtained by merging machine learning algorithms and data analytics. Farmers are able to make choices based on data on the timing of irrigation, the application of fertiliser, and the management of diseases, so increasing crop yields and reducing the amount of resources that are wasted [20].

2.4.3.2 Admistration of Irrigation

Internet of Things (IoT)-based irrigation systems increase the efficiency with which water is used by giving real-time data on soil moisture levels and environmental variables. The IoT platform receives continuous monitoring of the soil moisture content through moisture sensors that have been implanted in the fields themselves. Sophisticated analytics algorithms are able to evaluate this data and activate autonomous watering systems when the soil moisture level drops below a certain threshold [21].

IoT-based systems decrease water loss, eliminate over-irrigation or under-irrigation, and optimise plant water absorption. They do this by precisely managing irrigation based on real-time data. This allows the systems to optimise plant water uptake. As a consequence, this leads to increased agricultural output, greater water efficiency, and decreased overall energy usage.

2.4.3.3 The Supervision and Administration of Livestock

Technologies of the internet of things also have applications in the monitoring and management of cattle. Wearable technology can monitor the whereabouts, health, and behaviour of individual animals. Examples of this technology include smart collars and ear tags fitted with sensors. These gadgets have the capability to assess characteristics like as an animal's body temperature, heart rate, and activity levels, and provide real-time insights about how the animals are doing overall [22].

The data obtained from Internet of Things devices used with livestock enables early identification of infections, detection of estrus, and optimisation of feeding management. Farmers are able to take quick action to mitigate possible dangers and ensure the general health and production of their livestock by spotting abnormalities in the behaviour or health indicators of their animals and taking the appropriate steps in response [23].

2.4.4 Technologies and Device of the Internet of Thing (IoT) in Smart Farming

Smart farming systems rely on a diverse range of Internet of Things (IoT) technologies and sensors to streamline data gathering, transmission, and analysis. Various sensors, including those for soil moisture, temperature, humidity, and light, are strategically placed in the field to collect crucial environmental data. Actuators, such as valves and pumps, come into play to operate irrigation systems based on the information received from these sensors.

Facilitating communication and data transfer, gateways serve as central hubs, collecting information from an array of sensors and transmitting it to cloud-based platforms. These platforms, often referred to as "gateways," operate in the cloud and play a pivotal role in receiving, storing, and managing the data acquired through sensors. Their cloud-based nature simplifies the process of data analysis, visualization, and decision-making through the application of robust analytics algorithms.

Wireless communication technologies, such as Wi-Fi, Bluetooth, or cellular networks, enable seamless data transfer between sensors, gateways, and cloud-based platforms. This interconnected ecosystem of sensors, actuators, gateways, and cloud platforms forms the backbone of smart farming, optimizing agricultural processes and contributing to more informed decision-making in real-time.

network.

2.4.5 Agricultural Internet of Thing (IoT) Uses and Benefits

The use of IoT in agriculture offers numerous advantages, leading to increased productivity, sustainability, and resource efficiency. One key benefit is real-time monitoring, made possible by IoT systems. These systems provide immediate data on various environmental factors, facilitating prompt interventions and informed decision-making. With real-time information at their disposal, farmers can take timely actions to address issues and optimize farming practices.

Another advantage of IoT in agriculture is precision in resource management. By leveraging IoT technology, farmers can implement targeted irrigation and fertilizer application. This precision approach reduces resource waste and maximizes resource utilization. The IoT enables farmers to deliver the right amount of water and nutrients to plants based on their specific requirements, resulting in healthier crops and improved yields.

Productivity is also significantly increased through IoT-based solutions. By automating monitoring and control activities, IoT systems minimize the need for manual labor. This automation streamlines operations, reduces human effort, and allows for scalability. Farmers can monitor and manage their agricultural processes more efficiently, resulting in increased productivity and optimized resource allocation.

Furthermore, real-time monitoring and management of crops is a valuable aspect of IoT in agriculture. With the ability to monitor crops in real time, farmers can identify and address issues such as stress, diseases, or nutritional deficiencies at an earlier stage. This proactive approach leads to enhanced crop quality and higher yields. By promptly detecting and managing crop-related challenges, farmers can prevent or mitigate potential losses, ensuring the overall success of their agricultural endeavors.

In conclusion, the utilization of IoT technology in agriculture provides several advantages. Real-time monitoring enables prompt interventions and informed decision-making. Precision in resource management reduces waste and maximizes resource utilization. IoT-based solutions increase productivity by automating monitoring and control activities, minimizing the need for manual labor. Additionally, real-time monitoring and management of crops allow for early detection and mitigation of issues, resulting in improved crop quality and higher yields. By harnessing the power of IoT, farmers can enhance their agricultural practices and achieve greater levels of productivity, sustainability, and resource efficiency.

2.4.6 Challenges and Considerations for Implementing Internet of Thing (IoT) in Agriculture

The use of the Internet of Things (IoT) and data analytics are employed to enhance the operational efficiency and productivity in the agriculture sector. IoT is transforming real-world things into smarter devices and is applicable to a variety of application domains including agriculture. However, there are several challenges and considerations that need to be addressed when implementing IoT in agriculture.

2.4.6.1 Data Management

The field of intelligent agriculture still lacks comprehensive understanding of data management, primarily due to the limited availability of scientific publications on the subject. While the benefits of data management in this context are evident and significant, several challenges need to be addressed to fully harness its potential. These challenges encompass complexities in data integration, insufficient availability of skilled personnel and necessary resources, inadequate infrastructure, and the absence of robust data warehouse architectures. Thus, there is a need for further research and exploration to overcome these obstacles and establish a solid foundation for effective data management in the realm of intelligent agriculture [24].

2.4.6.2 Connectivity

In agricultural settings, particularly in remote rural regions, internet connectivity is frequently constrained or unreliable, posing significant challenges for maintaining consistent and dependable network access. This becomes particularly critical for Internet of Things (IoT) devices that rely on real-time data transmission. To address this issue, it becomes imperative to explore alternative connectivity options, including satellite-based networks or low-power wide-area networks (LPWANs), which can offer more reliable and continuous connectivity solutions [25].

2.4.6.3 Security

Security is a major concern in IoT-based agriculture systems. IoT devices are vulnerable to cyber-attacks, and the data collected by these devices can be sensitive and confidential [26] . It is important to ensure that the IoT devices are secure and that the data collected is protected from unauthorized access.

2.4.6.4 Cost

The implementation of Internet of Things (IoT) systems in the agricultural sector necessitates substantial initial expenses, encompassing the procurement and deployment of sensors, gateways, and infrastructure for data analytics. In order to justify the adoption of IoT technologies, farmers must meticulously evaluate the return on investment (ROI) and long-term cost advantages [27].

2.5 Solar Energy in Agriculture

2.5.1 Implementation of Solar Power in Agricultural Operations

Solar power may be used in many different ways within the agricultural industry, including the provision of electricity to run irrigation systems and other on-farm activities. The following are some important uses of solar energy in agricultural settings:

2.5.1.1 Irrigation Method Powered by the Sun

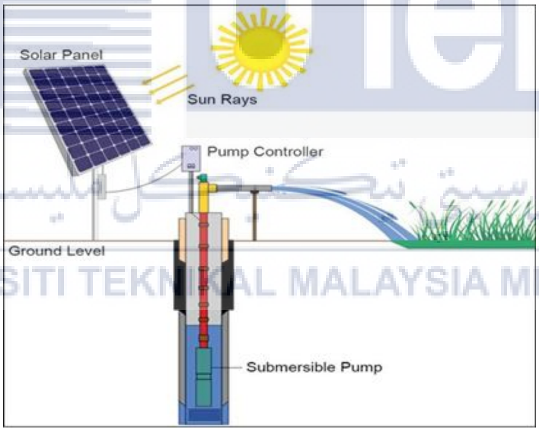


Figure 2.3 Solar powered irrigation.

Solar energy may be utilised to power irrigation systems, which guarantees a consistent and long-lasting supply of water for plants to grow in. Photovoltaic (PV) panels are able to collect solar energy, which may subsequently be utilised to power water pumps or other types of irrigation equipment. Irrigation systems that are powered by the sun provide enhanced autonomy and resilience, which is especially beneficial in places that are off the grid or in remote locations where access to energy may be restricted [28].

2.5.1.2 Solar-Powered Agricultural Operations

Solar energy may be used to fulfil the requirements for electricity that are necessary for agricultural operations. These requirements include lighting, heating, ventilation, and equipment. Farmers are able to create clean and renewable energy to power a variety of activities on their farms by placing solar panels on farm buildings or open land. This lessens their dependency on the local power grid and brings down the overall cost of running the farm.

2.5.1.3 Solar Drying and Heating

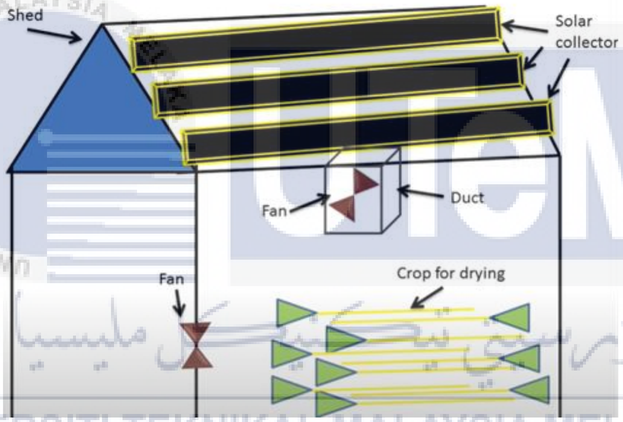


Figure 2.4 Solar powered crop drying and heating

Solar energy may be captured for the purpose of crop drying and space heating in greenhouses and other agricultural constructions. Solar dryers make advantage of the heat from the sun to extract moisture from crops, making post-harvest processing much more effective. Solar heating systems may also offer warmth throughout the winter months, helping to ensure that crops continue to have ideal growth conditions and so increasing agricultural output.

2.5.2 Solar Technologies in Agriculture

Agriculture makes use of a wide variety of solar technology in order to collect and put the sun's energy to work. The following is a list of important solar technologies that are employed in the agriculture sector:

2.5.2.1 Photovoltaic (PV) System

Also known as solar panels or modules, use the photovoltaic effect to directly convert sunlight into energy. Photovoltaic systems are often used to produce power for usage on farms in a variety of applications, including irrigation, lighting, and the operation of equipment.

2.5.2.2 Solar Thermal Systems

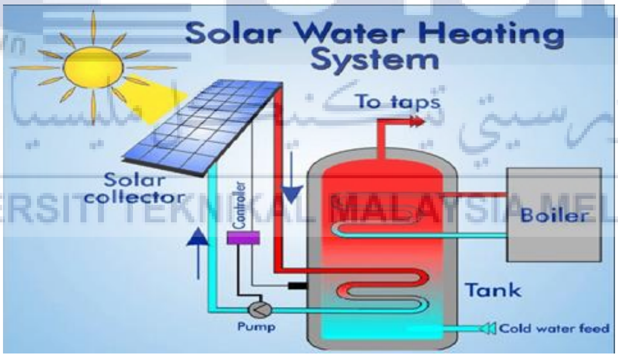


Figure 2.5 Solar Water Heating Process

This system collect solar energy to heat water shows in figure 2.5. Also for a variety of different uses. Solar thermal systems are also known as solar collectors. Solar thermal systems may be used in agriculture for a variety of purposes, including but not limited to space heating in greenhouses, water heating for animals, and even crop drying [29]. Solar collectors are used in these systems to gather heat from the sun and then transmit that heat to the target medium

2.5.3 Solar Power’s Benefits to the Agricultiral Industry

The use of solar energy in farming has a number of potential benefits, including increased longevity, reduced operating expenses, and improved conditions for the surrounding ecosystem. Listed below are some of the primary benefits:

2.5.3.1 Substainable and Renewable Source

Solar energy is a sustainable and renewable form of electricity that considerably lessens reliance on fossil fuels while also lowering the amount of greenhouse gas emissions that are produced. Farmers who switch to solar power may lessen their impact on the environment while also making a positive contribution to its long-term viability.

2.5.3.2 Cost Saving

Solar energy systems give long-term cost savings to farmers. According to study, solar panels have a lifetime of many decades and need very little maintenance after they have been installed [29] . Farmers may minimise their overall energy expenditures and lessen the effect of increasing power rates by producing their own electricity on their farms.

2.5.3.3 Energy Independence

Systems that are fueled by solar energy provide farmers with enhanced autonomy and resilience. Farmers who generate their own energy are not dependant on the power grid, which is particularly beneficial in locations that are off the grid or isolated and where the power infrastructure is either unreliable or inaccessible. This energy independence guarantees that vital agricultural processes will continue to run without interruption.

2.5.3.4 Increased Farm Productivity and Lower Energy Cost

Solar energy systems may increase the overall efficiency of farms by lowering energy costs and boosting the output of a wide variety of agricultural processes. Farmers are able to optimise their operations when they have access to a stable and cost-effective source of energy, which results in increased crop output and increased profitability.

2.5.3.5 Environmental Benefit

Solar energy lessens the negative effects that agriculture has on the environment by cutting down on the emissions of greenhouse gases and the air pollution that are caused by traditional energy sources. Solar energy production is compatible with environmentally responsible agricultural practises and lends assistance to the protection of the natural environment.

2.6 Previous Project Comparisons

Table 2.2 Comparison table between past related project

No	Author	Year	Title	Method	Advantage	Limitation
1	Kanumalli S Mantena S Kandula S Doppalapudi K Atluri T	2022	Automated Irrigation Management System using IoT [30]	1. Use soil moisture sensor and a temperature sensor. 2. Use NodeMcu as microcontroller. 3. cloud server to receive and store the sensor data	1. Precise irrigation: The system can provide the right amount of water at the right time, reducing water waste and increasing crop yield. 2. Remote monitoring and control: The user can monitor and control the irrigation system from anywhere, at any time, using a smartphone. 3. Cost-effective: This is a relatively low-cost project that can be implemented by small-scale farmers.	1. Limited range: The Wi-Fi range of the NodeMCU microcontroller is limited, which may not be suitable for large-scale farming operations. 2. Technical expertise: Setting up and maintaining the system requires some technical expertise, which may be a challenge for some farmers. 3. Reliance on technology: If the system fails or malfunctions, it can have a negative impact on crop yield and quality.
2	Sowmya.Turaka P.Pavani P.Yamini P.Venkata Madhavi, Ch.Venkateswari P.Sri Nandini	2022	IoT Based Plant Monitoring System Using NODEMCU [32]	1. NodeMCU 2. DHT11 Sensor 3. Soil Moisture Sensor. 4. Blynk App.	1. Reduces the need for daily watering of plants. 2. Improves plant growth and health. 3. Can be used for different types of plants. 4. Can be used for large-scale agriculture purposes to increase crop rate and reduce manpower. 5. Provides real-time monitoring of plant parameters.	1. Requires a stable Wi-Fi connection for the Blynk app to work. 2. May not be suitable for plants that require specific environmental conditions that cannot be measured by the sensors used in this project. 3. May require additional sensors or modifications for more accurate

						measurements. 4. May not be cost-effective for small-scale plant monitoring.
3	Santiago Jr. C,Murray J, Dizon S	2020	Plant Monitoring System for Vegetable Growers [33]	1. Descriptive-development design 2. Systematic Engineering Process 3. Arduino microcontroller and sensors for soil moisture, temperature, and humidity 4. Android Studio and Arduino Integrated Development Environment (IDE) for software development 5. Assessment by 120 evaluators consisting of farmers, agriculturists, and IT professionals	1. Automated system for monitoring soil moisture, temperature, and humidity of plants 2. Helps farmers water crops according to their needs, reducing water loss and constant supervision. 3. Low cost and provides an alternative solution for efficient water management. 4. Environmentally friendly with solar panel power. 5. Performs well in terms of functionality, durability, economy, safety, and saleability performed well in terms of functionality, durability, economy, safety, and saleability.	1. Needs improvement in durability. 2. Designed for vegetable growers and may not be suitable for other types of crops. 3. Requires Bluetooth connection, which may limit range 4. May require maintenance and calibration for accurate readings from sensors
4	Bhardwaj P, Srivastava A, Pandey A, Singh A, Tripathi B	2021	IoT Based Smart Agriculture Aid System using Raspberry Pi [34]	1. Arduino R3 microcontroller 2. Dht22 Temperature & Humidity Sensor 3. YL-69 Soil moisture Sensor. 4. Bluetooth Module 5. Android application for data collection	1. Efficient use of water resources: The system ensures that crops are irrigated only when required, thus reducing water wastage. 2. Increased crop yield: By providing crops with the right amount of water, the system can help increase crop yield. 3. Reduced labor costs: The system is automated and can be controlled remotely, reducing the need for manual labor. 4. Real-time monitoring: The system provides real-time data on	1. Initial setup costs: The system requires the installation of sensors, irrigation systems, and a central server, which can be expensive. 2. Technical expertise required: The system requires technical expertise to set up and maintain, which may not be available to all farmers. 3. Internet connectivity is required: The system requires internet

					soil parameters, allowing farmers to make informed decisions about irrigation.	connectivity to transmit data to the central server, which may not be available in all areas. 4. Weather monitoring is not available: The system does not include weather monitoring, which can affect the accuracy of irrigation.

CHAPTER 3

METHODOLOGY

3.1 Introduction

From the beginning, when the project was in the planning stages, until the end, when it was done, this chapter will look at the project's approaches. To achieve the project's purpose, the project methodology takes a few steps. As previously stated, a soil moisture sensor was selected to be employed in this project to monitor the moisture content of the soil during the duration of the project. NodeMcu ESP32 are the microcontroller and wireless communication technology utilized in this project. The user may watch the data collected over time using the Blynk application, which serves as the project's platform. The hardware and technique for the project will also be discussed in this chapter. This chapter also includes a flow chart, hardware and software implementation, and a project block diagram.

3.2 Project Workflow

Flowcharts are a useful tool for designing project management approaches because they provide a visual representation of the project. To produce a successful project on the next project, must have an amazing flowchart. The initial stage in the research procedure was to comprehend the title. Engineering research and studies published in peer-reviewed journals serve as a road map for constructing a highly desired or specific project. After that, I started working on a research canvas based on previous articles and journals related to the issue, which I discussed with my supervisor for approval. The obstacles, aims, questions, theoretical or conceptual framework, a strategy to answer the question section, expected findings, conclusion, and future work based on own title were determined and got supervisor approval once more after the research canvases were approved.

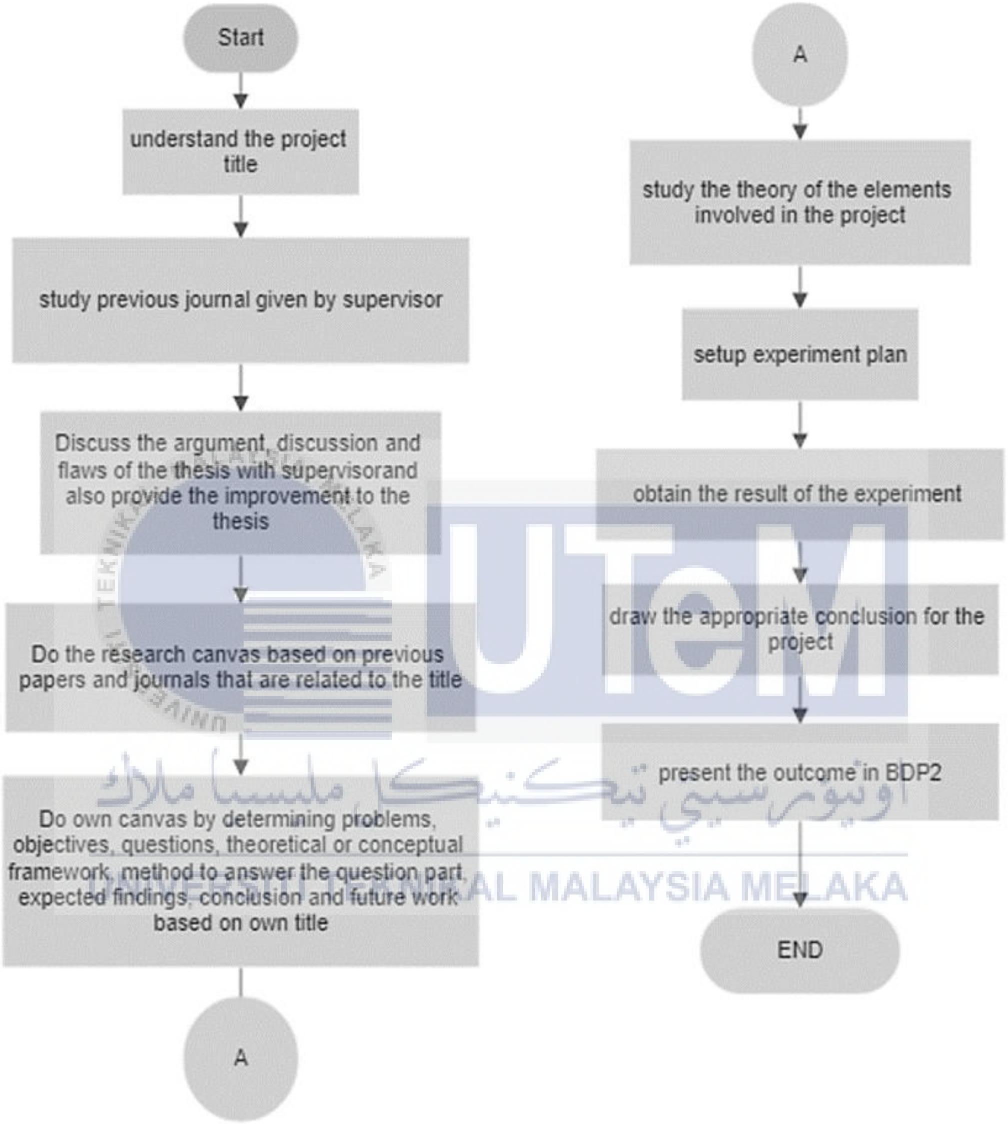


Figure 3.1 General Flowchart of The Project

3.3 Process Flow of The System

Figure 3-2 shows the flowchart of the system.

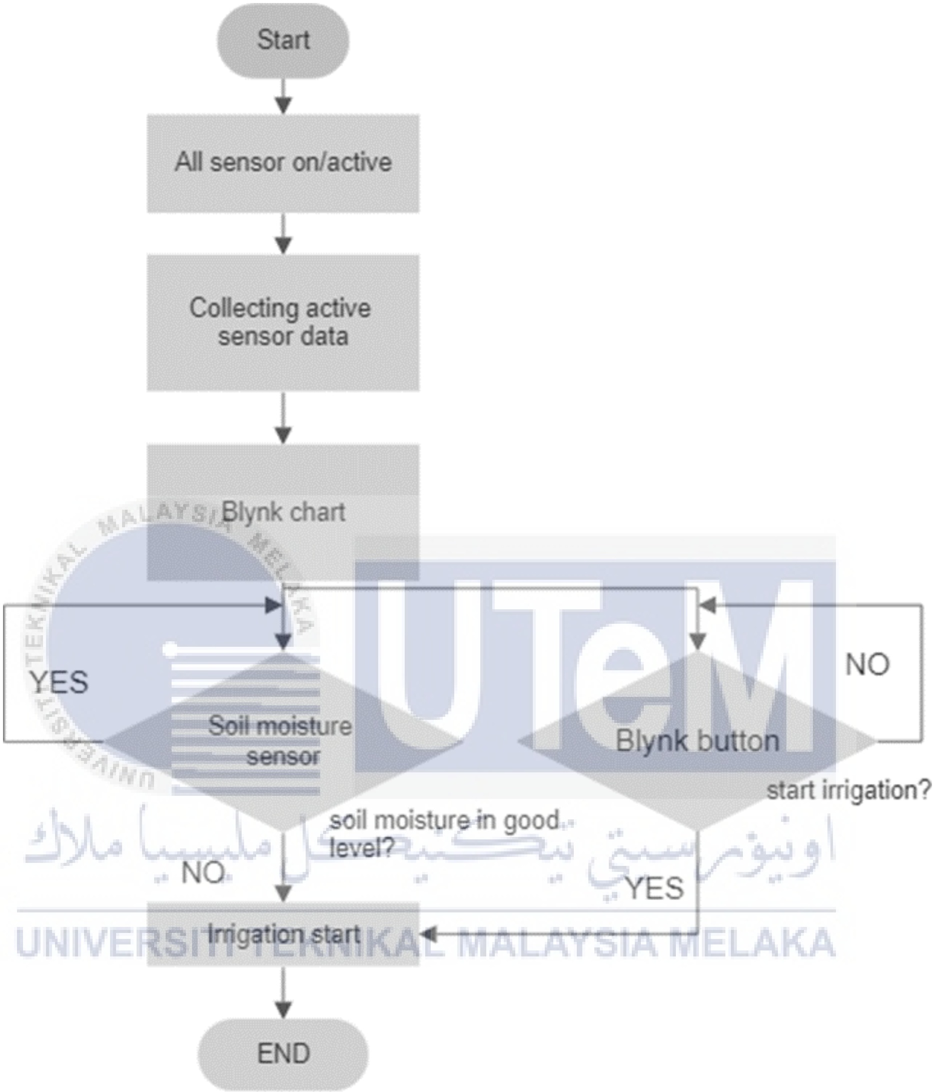


Figure 3.2 Flowchart of the system

3.4 Hardware Development

In this project covering microcontroller, sensors, solar panel and actuators for the plant monitoring and irrigation system. The function and application of each of the components with suitable circuit configuration are discussed in this chapter.

3.4.1 System Block Diagram

The block diagram represents the whole system, including the sensor unit-equipped system. A solar panel will be integrated to charge the power bank, and subsequently, the power bank will supply power to the NodeMCU. During the rainy season, a wall plug charger will be used to charge the power bank. Then soil moisture sensor will be installed on the plant tray and will be used to detect soil moisture. The ultrasonic sensor will then be inserted in the top of water tank in order to monitor the water level. After controller receive input from ultrasonic and soil moisture level sensor, it will control the water pump to make the water tank to supply water to the system. The DHT22 sensor will be installed on the plant tray in order measure temperature and humidty of plant surrounding. All the process will be conduct according to coding preset. After the process is done, data will be collected. Users can see all the data collected by using the Blynk app via mobile phone.

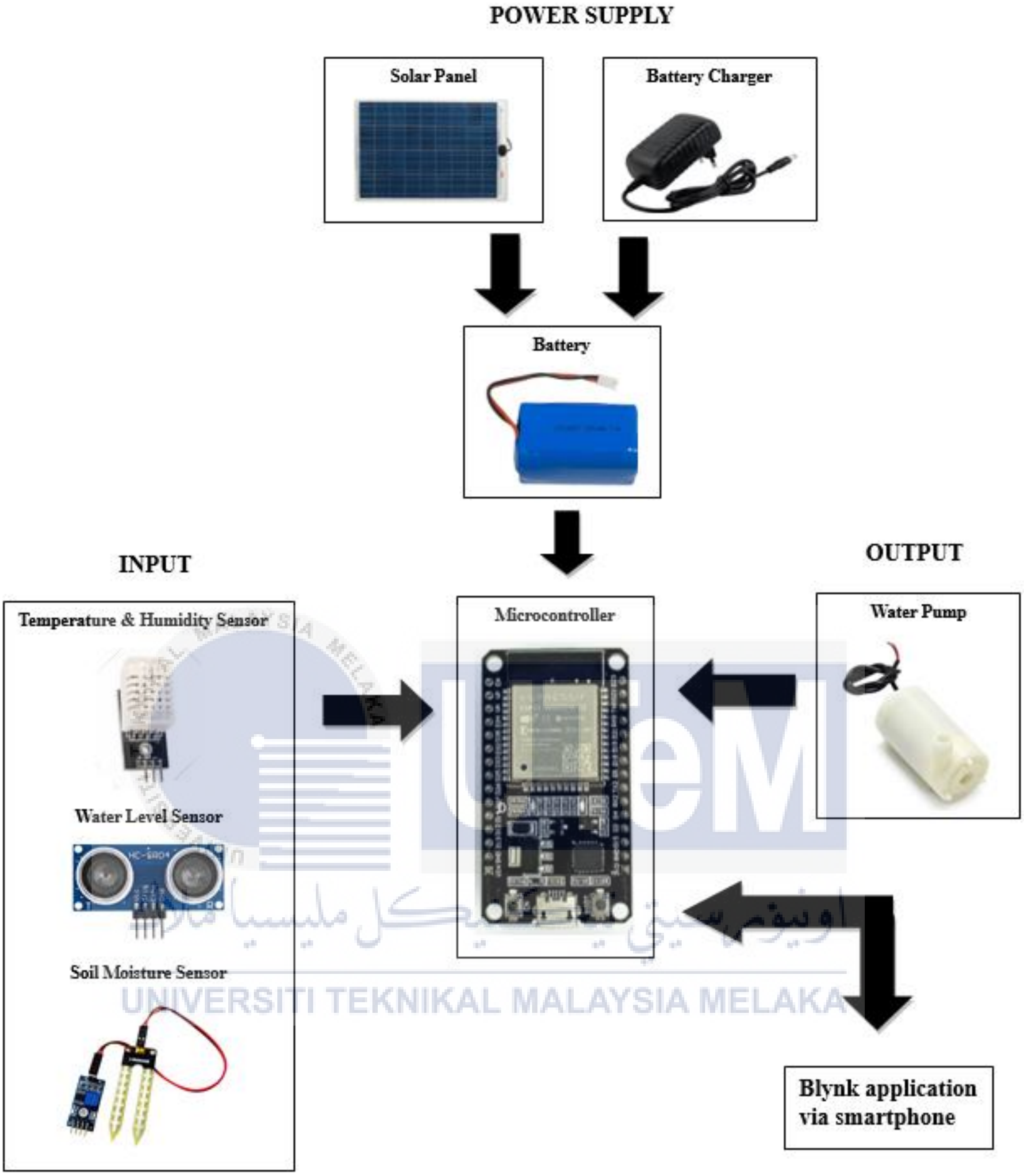


Figure 3.3 System Block Diagram

3.4.2 Component Selection

3.4.2.1 NodeMcu ESP32

Figure 3.4 NodeMcu ESP32

Based on the research microcontroller, ESP32 is strongly integrated with antenna switches, RF balun, power amplifier, low-noise receive amplifier, filters, and modules for power management. It can operate as a standalone system or as a slave device to a host MCU, lowering the communication stack overhead of the primary application CPU. ESP32 may communicate with other systems via its SPI / SDIO or I2C / UART interfaces to enable Wi-Fi and Bluetooth capability.

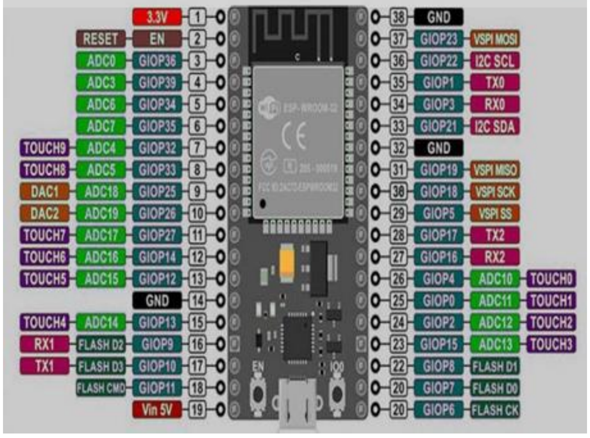


Figure 3.5 NodeMCU ESP 32 Pinout Diagram

3.4.2.2 Soil Moisture Sensor

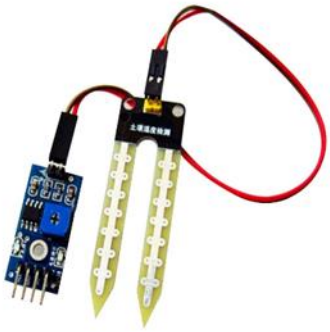


Figure 3.6 Soil Moisture Sensor

The moisture sensor in the soil measures the moisture content of the soil. It consists of two conductors, also known as electrodes, that are separated by a little distance. In addition to the digital pins, it contains Vcc, ground, and signal pins that offer a high or low output. The signal pin provides an analogue value proportional to soil moisture content. This sensor is put into the medium (soil, rockwool, coco, etc.) and provides a soil moisture reading that is exceptionally accurate. Currently, the software is configured to output a soil moisture level between 0 and 100 percent. This value can be calibrated for a particular soil type so that 100 percent indicates fully saturated soil and 0 percent indicates soil that is completely dry.

3.4.2.3 DHT22 Sensor

Figure 3.7 DHT22 Sensor

The DHT22 sensor is a widely used sensor for measuring temperature and humidity in the surrounding environment. It is a digital sensor that provides accurate and reliable readings. Similar to the moisture sensor, the DHT22 sensor consists of several components and pins for connectivity. The sensor typically includes three pins: Vcc (power supply), ground, and a signal pin for data transmission. The signal pin communicates with the microcontroller or other digital devices to provide temperature and humidity readings. To measure temperature and humidity, the DHT22 sensor utilizes a built-in temperature and humidity sensing element. This element consists of a thermistor to measure temperature and a capacitive humidity sensor to measure humidity. When the sensor is connected to a power supply and the appropriate communication lines, it can be used to obtain temperature and humidity data. The microcontroller or digital device sends a signal to request the data, and the DHT22 sensor responds by providing a digital output in the form of a series of pulses. The digital output from the DHT22 sensor needs to be decoded to obtain the actual temperature and humidity values. The sensor provides a 40-bit data packet, which includes the temperature and humidity readings, as well as checksum bits for data integrity verification. The software or code interacting with the DHT22 sensor can decode the data packet and extract the temperature and humidity values. These values can be further processed or displayed in the desired format. The DHT22 sensor can be calibrated and adjusted for specific applications or environments

3.4.2.4 Ultrasonic Sensor

Figure 3.8 Ultrasonic Sensor

One method for accurately measuring the water level in a tank involves the use of ultrasonic sensors. These sensors employ the transmission of short ultrasonic pulses to determine the travel time of the pulse, commonly known as the echo, to and from the surface of the liquid. By calculating the time taken for the echo to return, the distance between the sensor and the water's surface can be determined. To determine the water level in the tank, this distance is subtracted from the total depth of the tank. By utilizing this approach, precise measurements of the water level can be obtained, allowing for effective monitoring and control of the tank's contents. Ultrasonic sensors provide a non-contact and reliable solution for measuring water levels, offering accuracy and convenience in various applications such as industrial processes, water management systems, and storage tanks.

3.4.2.5 Relay

Figure 3.9 Relay

A relay serves as an electrical switch that enables the opening or closing of connections to activate or control other electrical devices. Its primary function is to monitor a specific area or system for any irregularities or anomalies, and based on the detected conditions, it instructs a circuit breaker to either turn the power ON or OFF to that particular section. The relay module is specifically designed to handle high-current loads, such as motors, AC wiring, and lights. It is designed to be used in conjunction with microcontrollers such as PIC, Arduino, or ESP32. By integrating this relay module into various applications, such as hydroponics systems, it becomes possible to conveniently control multiple components within a single package.

3.4.2.6 Water pump (Submersible)

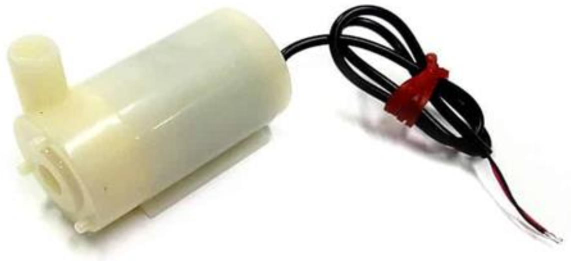


Figure 3.10 Water pump (Submersible)

A water pump motor, commonly known as a submersible pump, is specifically designed to be fully immersed in water. Its primary purpose is to pump liquid from a tank and deliver it to an irrigation system through a small tube, typically around 7 to 8mm in diameter. One significant advantage of a submersible pump is that it does not require priming before operation. This is because it is already submerged in the fluid it is intended to pump. As a result, the pump can start working immediately without any additional effort or preparation. Submersible pumps are highly efficient due to their unique design. They capitalize on the water pressure present in the system, which helps propel the water into the pump. This means that the pump doesn't have to exert much energy to draw water in, resulting in energy savings and increased overall efficiency.

3.4.2.7 Solar Panel

Figure 3.11 Solar Panel

A solar panel, also known as a photovoltaic (PV) panel, is a device that converts sunlight into electricity. It is composed of multiple solar cells made from semiconductor materials, typically silicon, which generate an electrical current when exposed to sunlight. Solar panels are designed to harness the renewable and abundant energy provided by the sun, offering a sustainable and environmentally friendly source of power. The sunlight that falls on the solar panel's surface is absorbed by the solar cells, causing electrons to be released and creating a flow of electric current. This direct current (DC) can be utilized to power various electrical devices or stored in batteries for later use.

3.4.2.8 Li-Ion Battery

Figure 3.12 Li-ion Battery

A lithium-ion (Li-ion) 3.7V battery is a type of rechargeable battery that operates at a nominal voltage of 3.7 volts. It is widely used in various electronic devices such as smartphones, laptops, tablets, digital cameras, and portable power banks. Li-ion batteries are known for their high energy density, which allows them to store a large amount of energy in a relatively small and lightweight package. This makes them suitable for portable electronics where size and weight are important considerations. The 3.7V rating refers to the average voltage of the battery during its discharge cycle. However, it's worth noting that the actual voltage of a Li-ion battery can vary between approximately 4.2 volts when fully charged and around 3 volts when fully discharged.

3.4.2.9 USB Boost Converter Module

Figure 3.13 USB Boost Converter Module

This module is a non-isolated step-up converter designed to take an input voltage range of 1-5V and provide a stable output in the range of 5.1-5.2V. It is capable of delivering a rated output current of 1A-1.5A, with an overall maximum output of 1.5A. The efficiency of the module can reach up to 96%, and it operates at a switching frequency of 500KHz. The output ripple is maintained at a maximum of 30mV within a 20M bandwidth, specifically at an input of 4V and an output of 5.1V with a load of 1A. The module features a voltage indication system using LED lights, with the indicator turning off when the input voltage drops below 2.7V. Operating in industrial conditions, it can withstand temperatures ranging from -40°C to +85°C, and even at full load, the temperature rise is limited to 30°C. This module is suitable for applications requiring efficient voltage step-up with stringent temperature and performance requirements..

3.4.3 System Component Configuration

A simple test is conducted to verify that the components utilised in this system tool perform as expected in order to assure their proper operation. Basic programming commands are created in the ESP32 open source software and then programmed into the microcontroller to execute the test. Then, fundamental circuits are set up to execute these tests.

3.4.3.1 Soil Moisture sensor IO pins Circuit

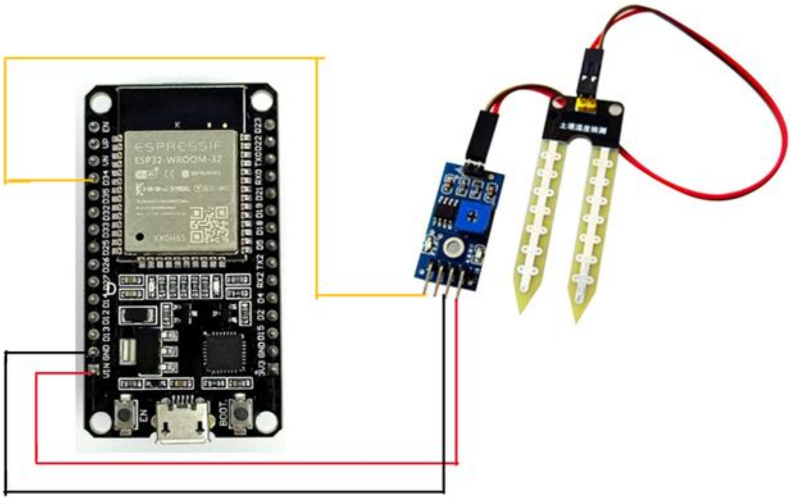


Figure 3.14 Circuit Diagram for Soil Moisture sensor Test

The pinout of soil moisture is which is A0 pin is connected to GPIO 34 ESP32 microcontroller’s pin. Then the 3.3V power supply will connect directly to the soil moisture module. The module consists of potentiometer to set the threshold by adjusting the sensitivity of the digital output. So when the moisture level exceeds the threshold, the module will have output LOW, otherwise, it will have output HIGH.

3.4.3.2 Temperature and Humidity (DHT22) sensor IO pins Circuit

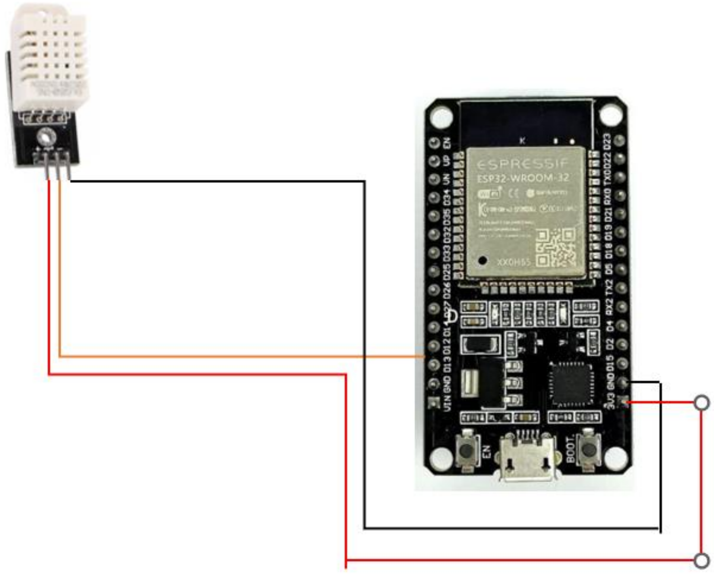


Figure 3.15 Circuit Diagram for DHT22 sensor Test

The pinout of Temperature and Humidity is connected to GPIO 13 ESP 32 microcontroller's pin. Then the 3.3V power supply will connect directly to the sensor.

3.4.3.3 Ultrasonic sensor IO pins Circuit

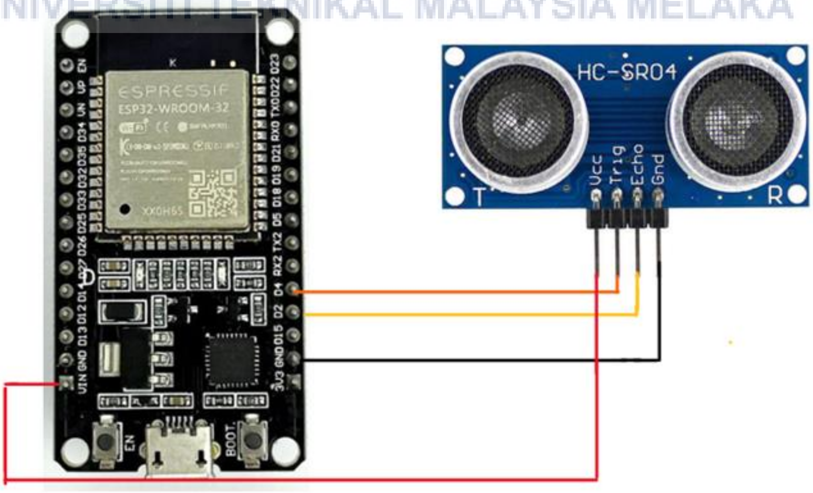


Figure 3.16 Circuit Diagram for Ultrasonic Sensor Test

The pinout is determined for each input which is ECHO pin and TRIG pin are connected to GPIO 2 and 4 microcontroller’s pin respectively. Trig pin will received a control pulse from microcontroller and emits a high-frequency sound (40 kHz) while Echo pin receives the reflected sound once it bounce back to the module and generates a pulse corresponding to the measurement distance to microcontroller. The 3.3V power supply will connect directly to the sensor.

3.4.3.4 Water pump IO pins circuit

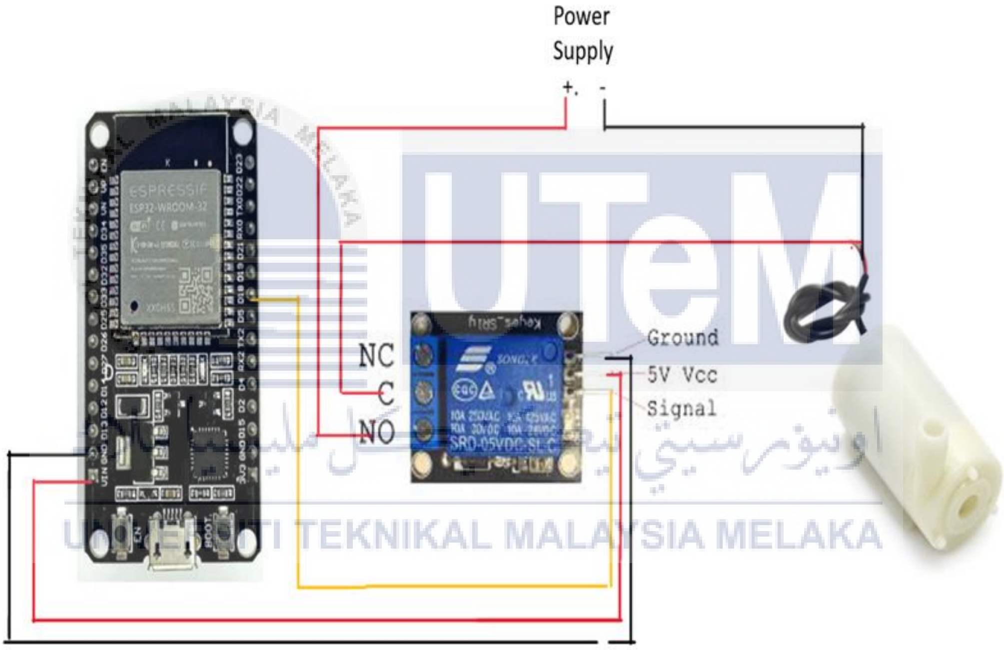


Figure 3.17 Circuit Diagram for Waterpump Test

The water pump is connected to relay in order to activated it. From relay 5V vcc will connected to 3.3V. Signal terminal from relay will connected to GPIO 18 esp32 microcontroller’s. For waterpump we need to connect to another power source because esp32 microcontroller do not have enough voltage to activated the waterpump.

3.4.3.5 16x2 LCD IO Pins Circuit

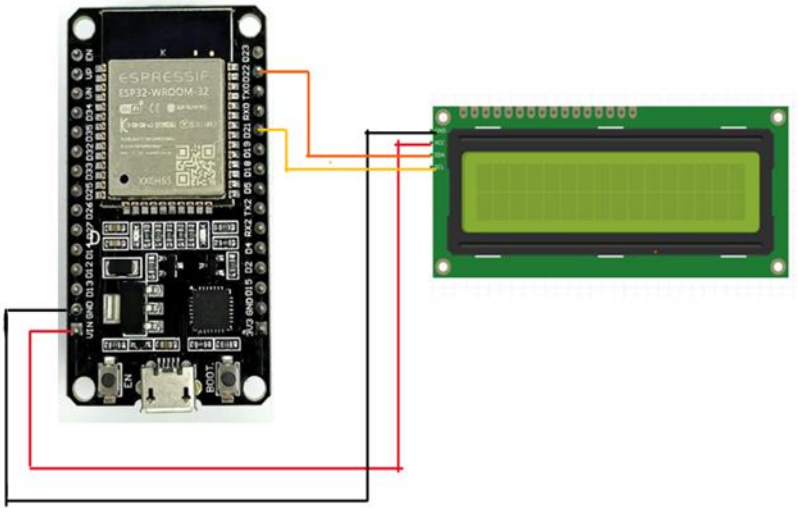


Figure 3.18 Circuit Diagram for 16x2 LCD Test

A simple circuit that consists with a 16X2 LCD is connected to the ESP32 microcontroller. The microcontroller that used in this system tool is NodeMCU ESP32 and the pinout is determined for each input which is SDA pin and SCL pin is connected to GPIO 22 and 21 ESP32 microcontroller’s pin respectively. Then the power supply will connected directly to the 16X2 LCD display module since this display module can receive range of voltage source from 3V to 5V.

3.5 Software Development

3.5.1 Arduino IDE

The Arduino Software (IDE) is a free and open-source cross-platform program (for Windows, macOS, and Linux) that makes it simple to write code and upload it to the Arduino microcontroller board. It allows the user to program the Arduino microcontroller by simply selecting the relevant port and Arduino model in the program settings, after which the coding is retrieved into the appropriate microcontroller. This application has a basic user interface and is easy to create with; thousands of libraries can be readily loaded and utilized. This software is compatible with all Arduino boards. The Arduino programming environment includes a text editor for writing code, a message box, a text terminal, a toolbar with buttons for basic activities, and a series of menus. It communicates with the Arduino hardware and transfers programming to it.

```
void setup() {
  // put your setup code here, to run once:

}

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

}

```

Figure 3.19 Arduino IDE Interface.

3.5.2 BLYNK

Blynk is an iOS and Android platform with apps for managing Arduino, Raspberry Pi, and other Internet-connected devices. The Google Play Store for Android and the Apple App Store for iPhone both have these apps available for download. It's a digital dashboard that lets you drag and drop widgets to create a project's graphical interface. Blynk isn't bound to any one board or shield. Instead, it is compatible with the hardware you want to use. The platform is made up of three major components:

- Blynk App - with the help of our various widgets, you may create gorgeous interfaces for your projects.

- Blynk Server - manages all phone-to-hardware interactions. You may use our Blynk Cloud or set up your own private Blynk server on your own computer. It's free and open source, with the ability to support thousands of devices. It can even operate on a Raspberry Pi.
- Blynk Libraries - on all main hardware platforms, allow connectivity with the server and process all incoming and outgoing commands.

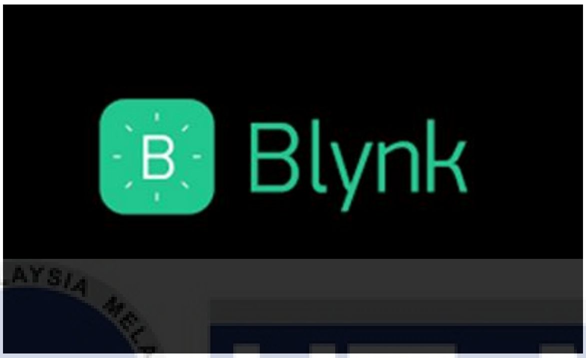


Figure 3.20 Blynk

CHAPTER 4

RESULTS

4.1 Introduction

This section provides the findings, analysis and discussion of all data acquired from the system to access its performance and adjust it to attain the best possible results for this plant monitoring and irrigation system project.

4.2 Result and Analysis

This section describes the analysis and discussion of all the data obtained from this product sample model. This research is conducted to satisfy the need of the objective for this final project. In order to ensure the correctness of the results and the performance of the Plant Monitoring and Irrigation System, the results are collected using a variety of techniques and sample sets.

4.2.1 System Functionality

This project utilizes a solar power bank as its power supply, with a 6V 10W-rated solar panel. The solar panel is connected to the power bank, which, in turn, is connected to the NodeMcu. The system employs a soil moisture sensor to monitor the soil moisture threshold, triggering irrigation through a water pump for the plant crop. Additionally, a DHT22 sensor is integrated to provide surrounding conditions for plant monitoring. An ultrasonic sensor monitors the water tank level and alerts the user to ensure that the water tank level is always sufficient.

All data parameters are displayed in the Blynk application. Through Blynk, users receive notifications indicating when to irrigate the crops and when to top up the water in the tank. Users can irrigate the plants from any location by simply triggering the button on the Blynk application.

4.2.2 Hardware Prototype View

This section shows that the actual view for the hardware prototype display. Figure 4.1 show overall project prototype. Figure 4.2 show inside of control box. Figure 4.3 show inside of powerbank storage. Figure 4.4 show placement of DHT22 sensor on side of plant tray. Figure 4.5 show placement of soil moisture sensor, inside of crop. Lastly, Figure 4.6 show placement of ultrasonic sensor, in top of system water tank.

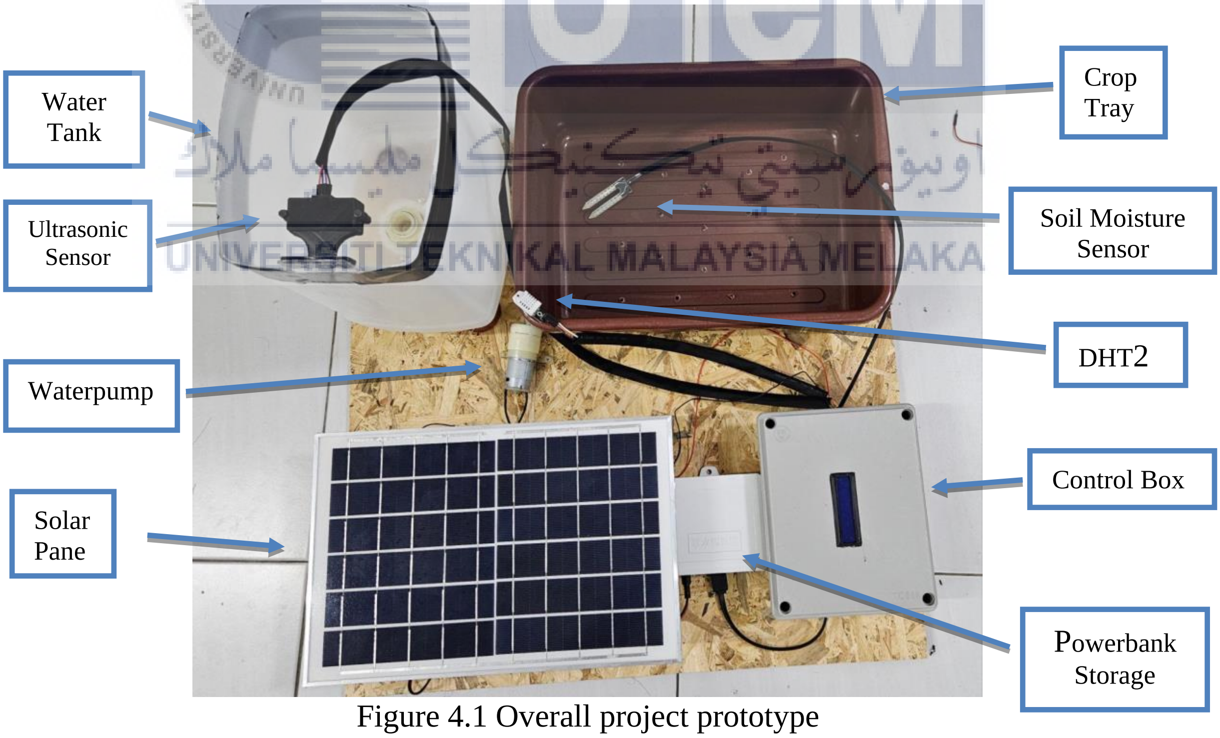


Figure 4.1 Overall project prototype

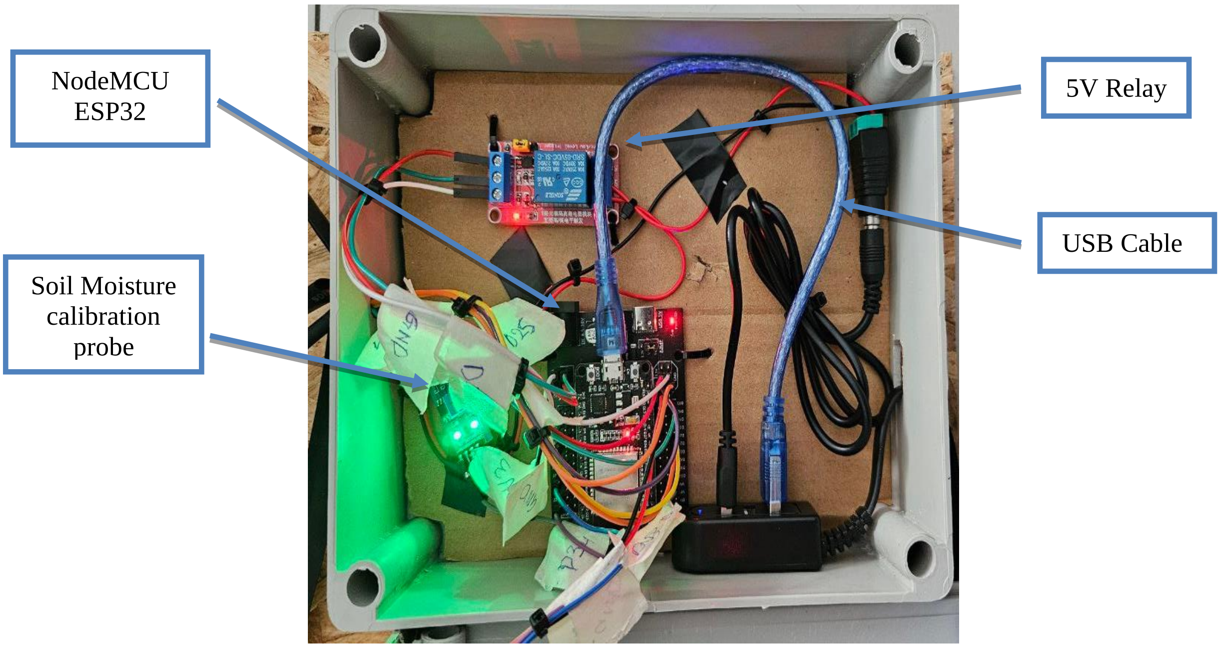


Figure 4.2 Top view inside control box

Figure 4.3 Top view inside powoerbank box

Figure 4.4 Side view DHT22 Sensor Placement

Figure 4.5 Top view Soil Moisture Sensor Placement

Figure 4.6 Top view Ultrasonic Sensor Placement

4.3 Performance Analysis

4.3.1 Battery-based solar charging system analysis

On this part, three data samples were collected from 9 am to 5 pm. to show the difference in voltage and current for one day. As a result, the voltage and current readings are shown in recorded tables and plotted graphs.

According to Table 4.1, the current reading is exceptionally low, attributed to the presence of clouds and drizzle persisting from morning until evening. Figure 4.7 illustrates that the maximum power for the day occurs at a current value of 0.48A. Although it is still capable of charging the battery storage, as the voltage has reached 4V, the charging process is notably sluggish.

Table 4.1 Reading voltage and current for sample 1

TIMES (HOURS)	VOLTAGE (V)	CURRENT (A)
9 AM	4.12	0.16
10 AM	4.11	0.14
11 AM	4.13	0.16
12 PM	4.16	0.20
1 PM	4.19	0.48
2 PM	4.18	0.43
3 PM	4.17	0.36
4 PM	4.10	0.13
5 PM	4.09	0.11

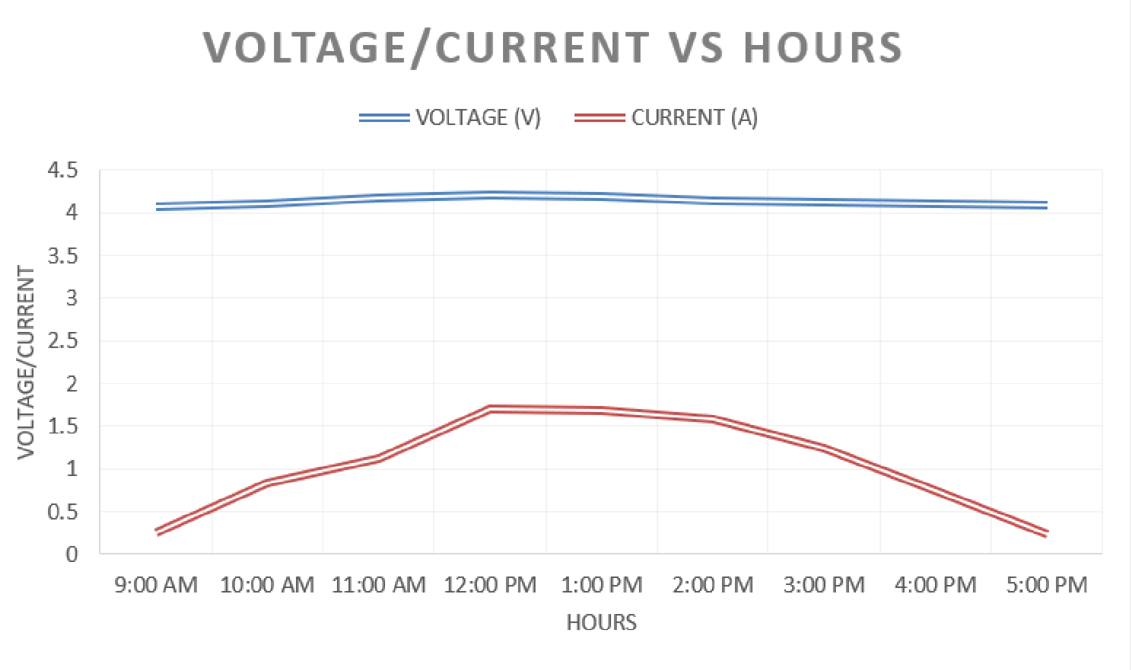


Figure 4.7 Graph of reading voltage and current for sample 1

According to Table 4.2, the voltage reading remains stable from morning until evening. Figure 4.8 illustrates that the maximum power for the day occurs at a current value of 1.26A at 1:00 PM. As depicted in Figure 4.8, at 3:00 PM, the current drastically drops due to the onset of rainy weather. In Sample Two, it is evident that the battery storage can be charged more rapidly because the current reading is high from 11:00 AM to 2:00 PM.

Table 4.2 Reading voltage and current for sample 2

TIMES (HOURS)	VOLTAGE (V)	CURRENT (A)
9 AM	4.09	0.44
10 AM	4.15	0.61
11 AM	4.20	0.86
12 PM	4.21	1.10
1 PM	4.22	1.26
2 PM	4.19	1.09
3 PM	4.13	0.24
4 PM	4.10	0.19
5 PM	4.09	0.16

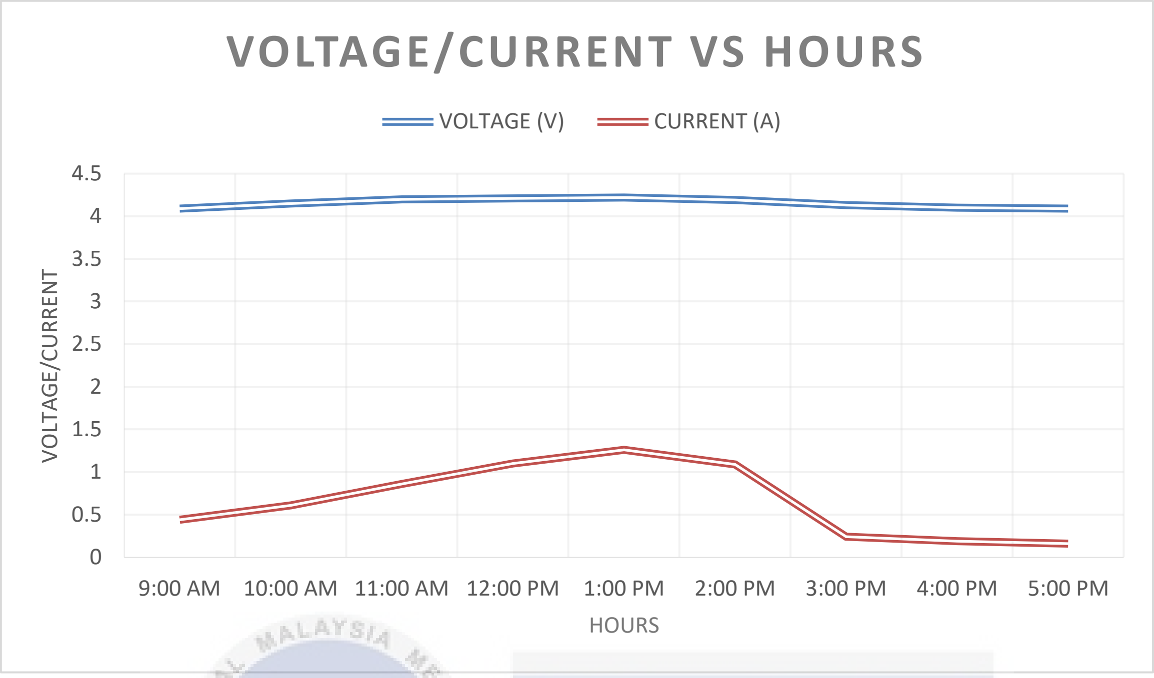


Figure 4.8 Graph of reading voltage and current for sample 2

According to Table 4.3, the voltage reading remains stable from morning until evening. Figure 4.9 illustrates that the maximum power for the day occurs at a current value of 1.71A at 12:00 PM. As depicted in Figure 4.9, it can be observed that the current on that day is very high due to sunny weather from morning until evening. In Sample Three, it is evident that the battery storage can be charged more rapidly because the current reading is high almost all day.

Table 4.3 Reading voltage and current for sample 3

TIMES (HOURS)	VOLTAGE (V)	CURRENT (A)
9 AM	4.08	0.26
10 AM	4.10	0.83
11 AM	4.18	1.12
12 PM	4.20	1.71
1 PM	4.19	1.68
2 PM	4.14	1.59
3 PM	4.13	1.24
4 PM	4.10	0.74
5 PM	4.09	0.24

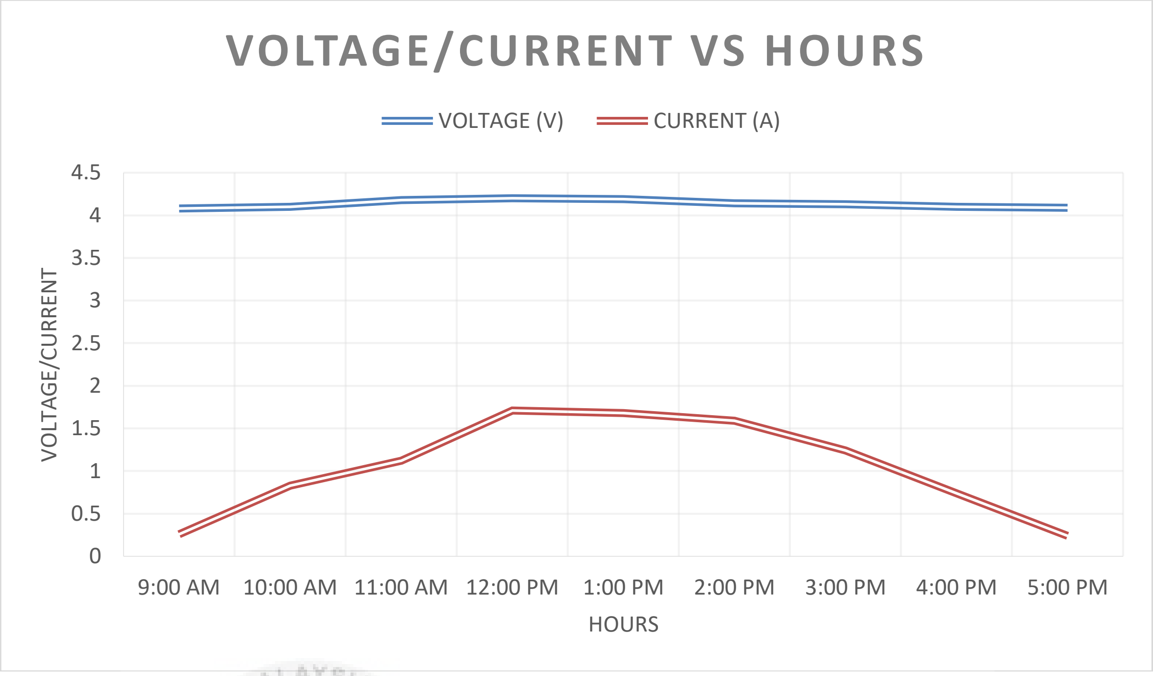


Figure 4.9 Graph of reading voltage and current for sample 3

Based on the result of three samples, it can be concluded that the solar system set up for the project is capable of charging the power bank. However, the charging speed is dependent on the weather conditions on those days. The more sunlight there is, the higher the speed at which the solar system can charge the power bank.

4.3.2 The accuracy of temperature and humidity sensor by comparing the data value with weather forecast.

In this experiment, the sensor are placed at the same location and time from 9am – 9pm to measured the temperature and humidity. In Figure 4.10, the DHT22 sensor was positioned on the side of the plant tray to monitor the temperature and humidity of the surroundings. Based on table 4.4 and table 4.5, data are taken from Durian Tunggal to see the range of the result in span of 12 hours.

Figure 4.10 Temperature and Humidity Sensor on plant crop

Table 4.4 Temperature Data

Hours	Weather Forecast Temperature (℃)	Measured Temperature (℃)
9 AM	26	27
10 AM	25	26
11 AM	25	26
12 PM	28	29
1 PM	29	31
2 PM	29	30
3 PM	26	27
4 PM	25	27
5 PM	25	24
6 PM	26	26
7 PM	26	25
8 PM	26	24
9 PM	26	26

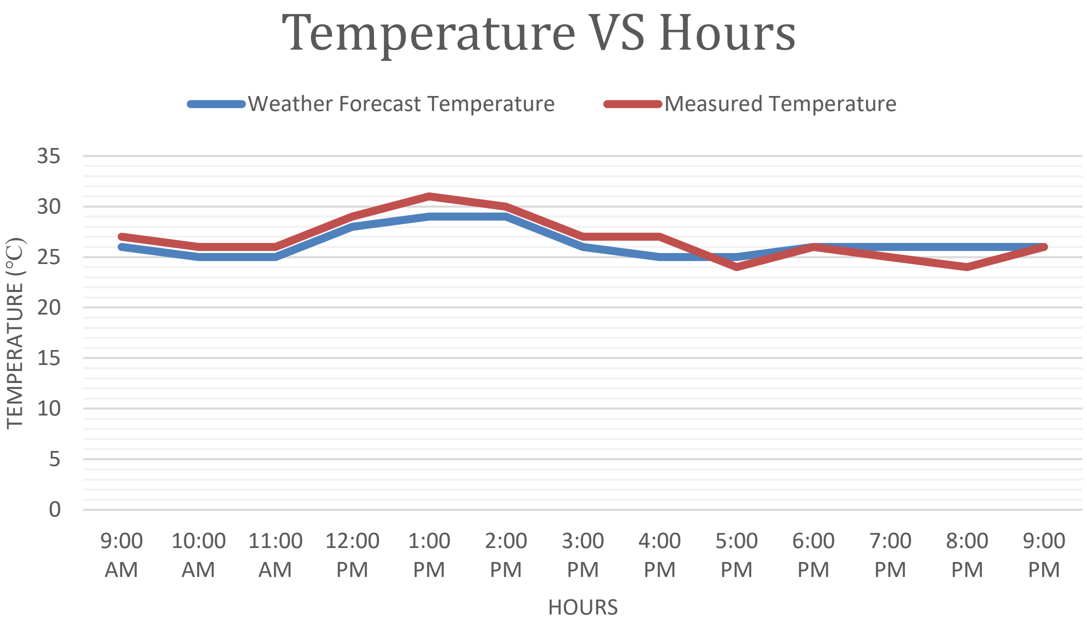


Figure 4.11 Temperature comparison chart

Environment temperature value is an additional data that has been add to this system to monitor the optimum environment's temperature to the plants. Ideal temperature for most plant is in between 23-35 °C including the plant that has been tested with the system which is spinach.

Based on figure 4.11, it can be seen that there is not much difference in the values, as the data is plotted almost at the same point for temperature. Due to a ±2% error accuracy, as stated in the sensor datasheet, resulting in small differences between the data taken, the sensors can be deemed as accurate.

Table 4.5 Humidity Data

Hours	Weather Forecast Humidity (%)	Measured Humidity (%)	Error (%)
9 AM	89	91	2.2
10 AM	94	94	0
11 AM	94	96	2.1
12 PM	84	86	2.3
1 PM	79	82	3.8
2 PM	74	77	4.0
3 PM	94	94	0
4 PM	100	95	5.3

5 PM	100	96	4.1
6 PM	94	93	1.1
7 PM	89	89	0
8 PM	94	92	1.1
9 PM	89	90	1.1`

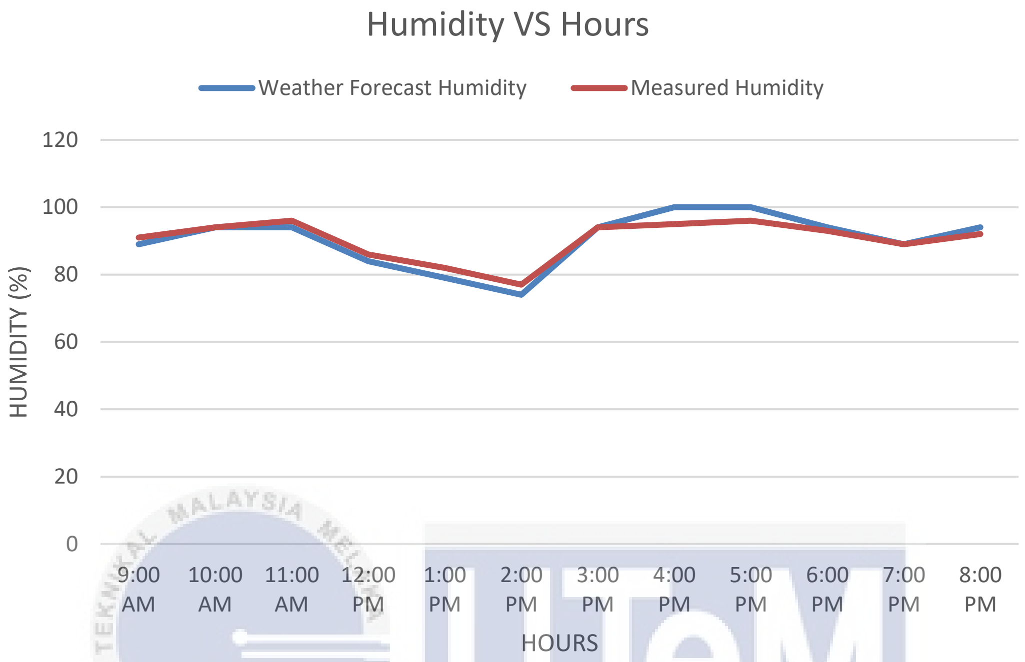


Figure 4.12 Humidity Data Comparison Chart.

Humidity value is an additional data that has been add to this system to monitor the optimum environment's humidity of the plants. The best humidity value for most of plant is around 60%-80% including the plant that has been tested with the system which is spinach.

Based on figure 4.12, it can be seen that there is not much difference in the values, as the data is plotted almost at the same point for humidity. Due to a ±2-5 % error accuracy, as stated in the sensor datasheet, resulting in small differences between the data taken, the sensors can be deemed as accurate.

4.3.3 The accuracy of soil moisture level sensor reading and irrigation system

In this section, data were collected every hour throughout the week of observation while the system operated daily. During the two days of observation, the weather remained hot. As shown in Figure 4.13, the soil moisture sensor is embedded in the plant crop to obtain soil moisture values for the crop.

Figure 4.13 Plant Crop with Soil Moisture Sensor

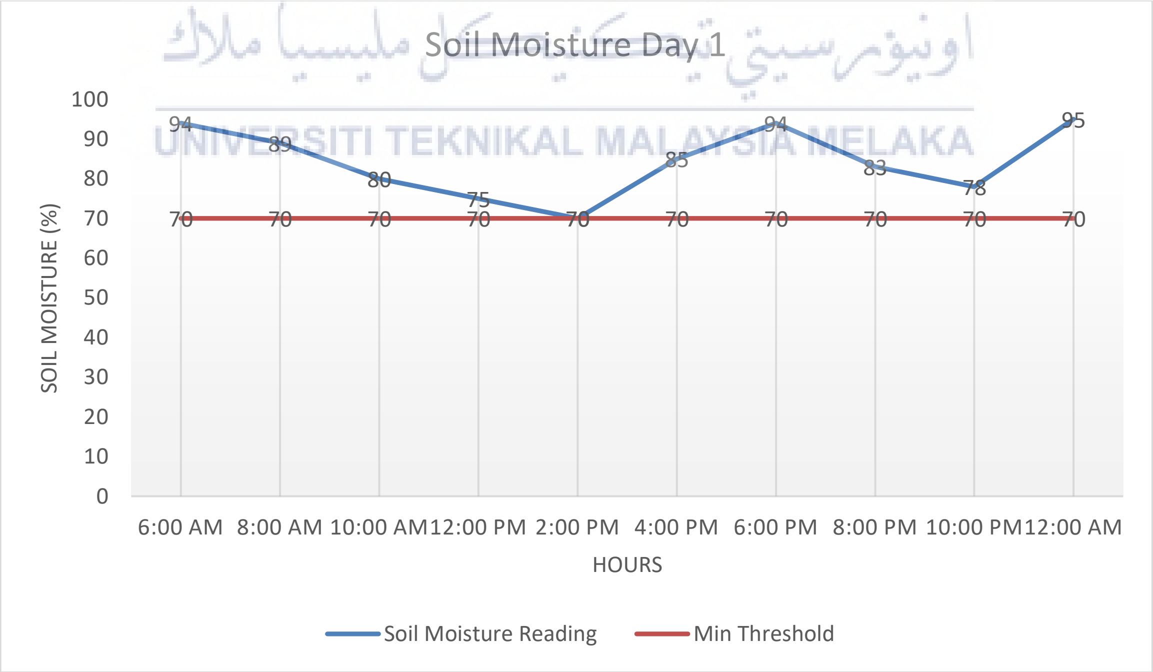


Figure 4.14 Soil moisture data day 1

As depicted in Figure 4.14 and Figure 4.15, the collected data from the graphs varies between each day. This discrepancy is attributed to the influence of surrounding conditions, particularly in terms of temperature and humidity.

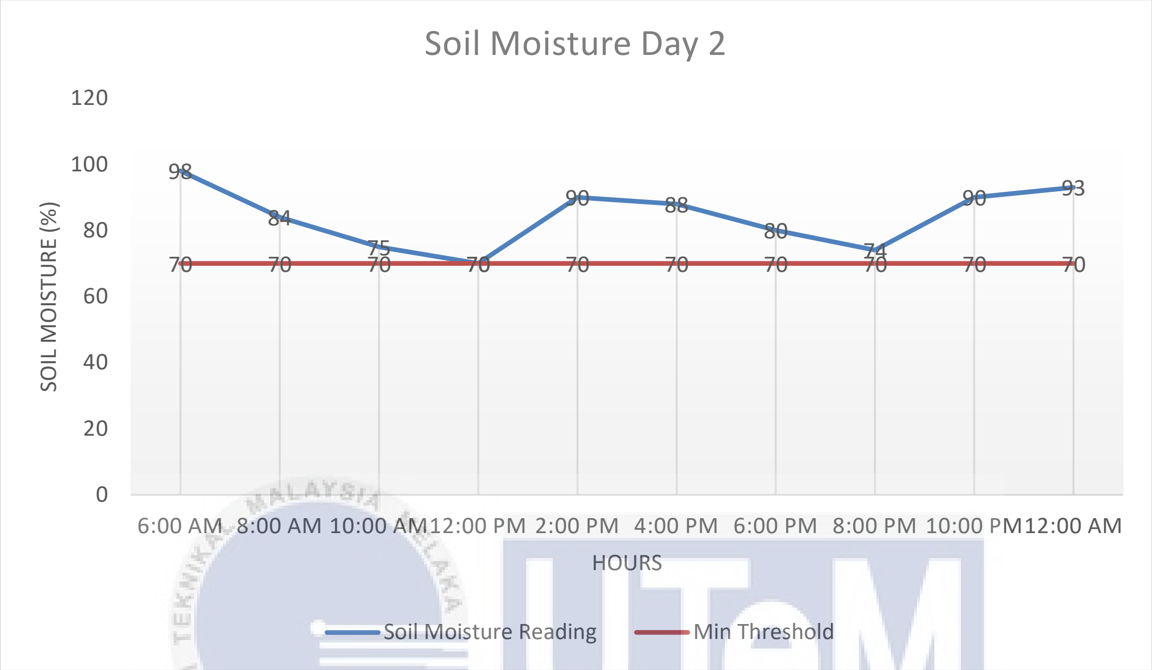


Figure 4.15 Soil moisture data day 2

The soil moisture sensor is employed to obtain readings of the soil moisture level. The optimal condition for plant survival dictates that the soil should not be excessively wet or waterlogged. Consequently, the system has been configured to send an alert warning to the user to irrigate the soil only when the moisture level falls below 70, considering that the moisture level readings range from 0 to 100.

It can be concluded that this system is effective, as indicated by the graph. The moisture level never drops below the minimum threshold for soil moisture since irrigation commences when the soil moisture level decreases below 70.

4.3.4 The water comsumption

In this section, all the data recorded for water consumption used in the irrigation process is documented in Table 4.6. The experimental setup involved two plant trays: based on Figure 4.16 show, Plant Tray A, which utilized an IoT plant monitoring and irrigation system, and based on Figure 4.17 show, Plant Tray B, which employed a traditional irrigation system. Data collection was scheduled daily at 12 PM over a span of 7 days. Both plant trays had identical measurements for the plant tray and water tank (Width: 14 cm, Height: 26 cm, Length: 21 cm).

Figure 4.16 Plant Tray A

Figure 4.17 Plant Tray B

Table 4.6 Water comsumption for the irragation process

Days	Plant Tray A (Liter)	Percentage (%)	Plant Tray B (Liter)	Percentage (%)
1	6.5	89	7.3	100
2	5.0	68	7.3	100
3	4.7	59	7.3	100
5	5.3	73	7.3	100
6	5.5	75	7.3	100
7	4.4	60	7.3	100
Total Water Used	**31.4**	**61**	**51.1**	**100**

For Plant Tray B, the traditional irrigation system involves applying a fixed amount of water, approximately 7.3 liter per day, during the irrigation process. While Plant Tray A used the data collected from the ultrasonic sensor to measure the water consumed for the irrigation process via the IoT of the system. For calculating the water consume in

Plant Tray A, the ultrasonic which is placed on the top cover of the water tank will measure the water left after the water sprinkler with the water pump does the irrigation process. The water level data collected were measured in terms of the height (in centimeters) of the water tank and subsequently converted to liter.

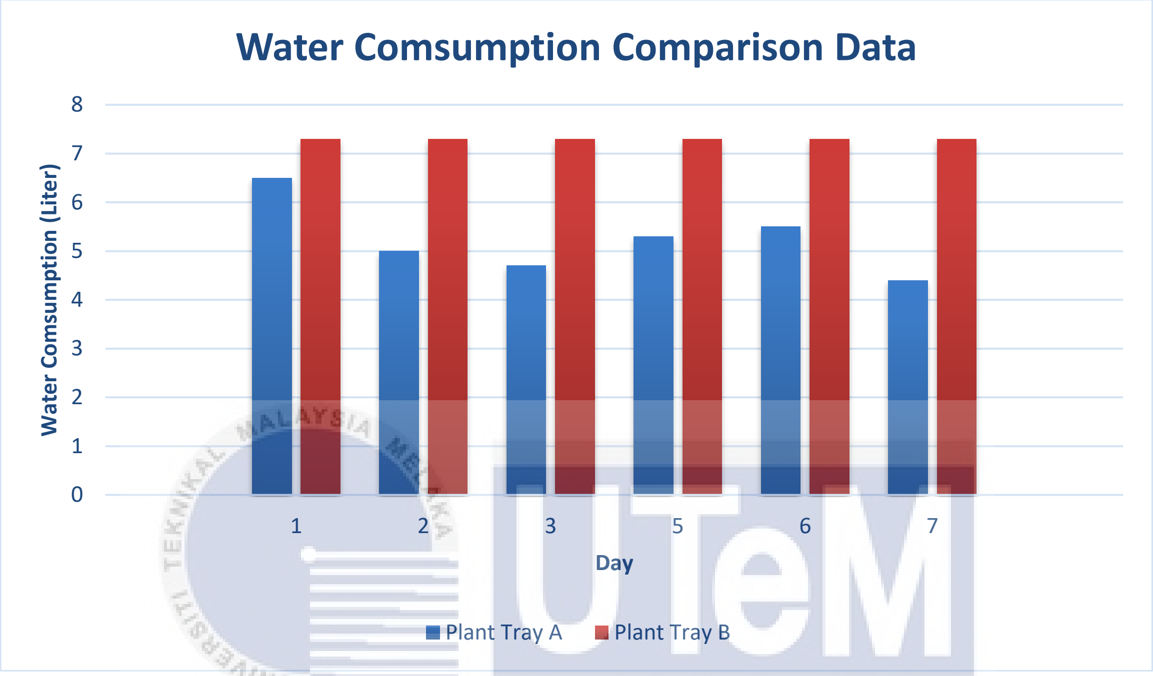


Figure 4.18 The graph result of water comsumption for 7 days

Hence, the results obtained from Table 4.6 and Figure 4.18 indicate that Plant Tray A has the capability to conserve water resources in the irrigation process through the implementation of the IoT plant monitoring and irrigation system. Water conservation stands out as a significant concern aimed at improving the efficiency and application for gardeners in plant irrigation processes. It can also be inferred that the wastage of water can be mitigated through the utilization of this system, ensuring water is supplied to the crops only when the soil moisture level drops below 70.

4.3.5 Growth of the spinach

When setting up the plant monitoring and irrigation system, spinach is initially planted in the soil. Once the system is fully operational, the spinach is transferred from the soil to a crop tray. The height of the plants is then measured using a ruler. Over the course of 4 weeks, the spinach is measured on a weekly basis, and the height and growth are recorded in the table.

Based on Table 4.7, two plant trays were set up in this experiment for the purpose of making a comparison. The hardware setup for Plant Tray A as shown in Figure 4.19, utilized an iot plant monitoring and irrigation system, while Plant Tray B as shown in Figure 4.20, employed traditional farming methods.

Figure 4.19 Plant Tray A

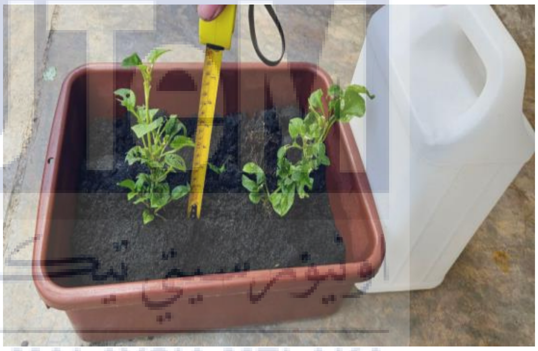


Figure 4.20 Plant Tray B

Table 4.7 Plant growth data collectrion

Weeks	**Plant Tray A (cm)**	**Increases (%)**	**Plant Tray B (cm)**	**Increases (%)**
1	4.11	-	3.5	-
2	6.17	50	4.2	20
3	9.5	54	6.16	47
4	11.5	21	8.7	41
Total Growth		125%		108%

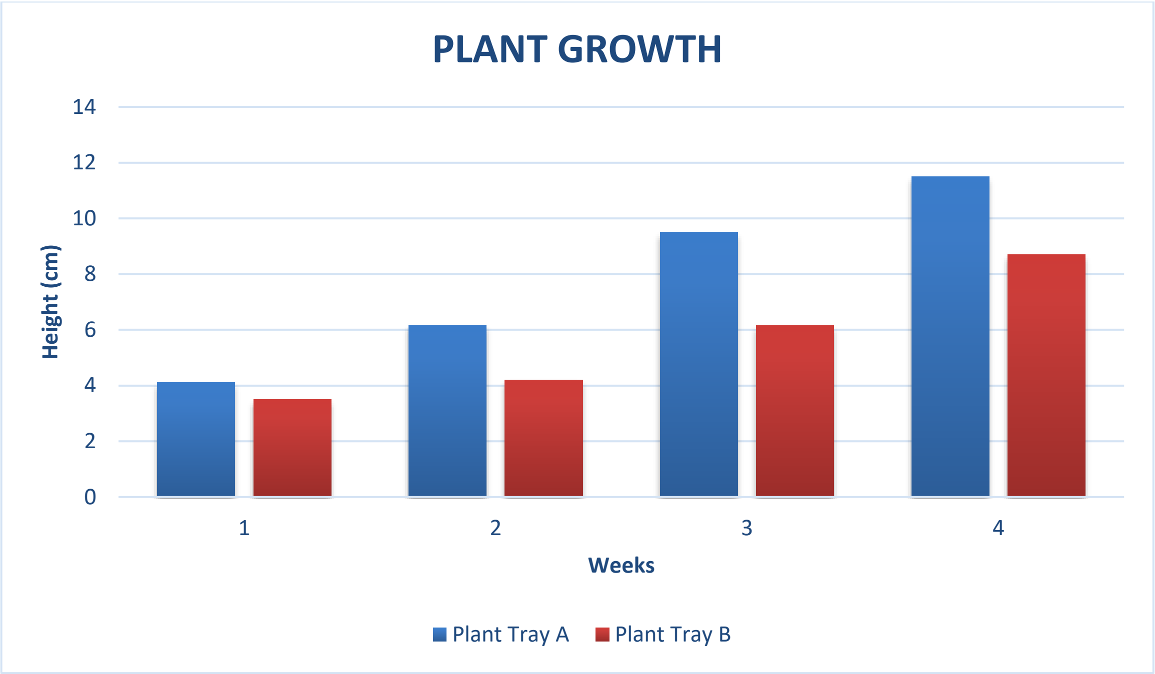


Figure 4.21 Data comparison for plant growth

As shown in Figure 4.21, it can be observed that the spinach in Plant Tray A exhibits a better growth rate compared to the spinach in Plant Tray B. This difference is attributed to the efficiency of irrigation control and surrounding monitoring. Plant Tray A has better control in terms of irrigation, facilitated by the presence of a soil moisture sensor that was planted in the tray. This sensor detects soil moisture, allowing for accurate determination of the optimal time to irrigate the plants.

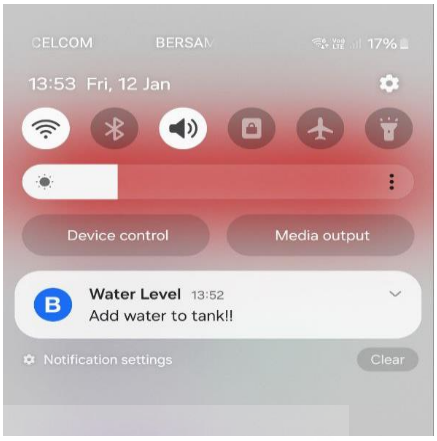
We can conclude that the plant monitoring and irrigation system functions effectively, as it contributes to a slightly better growth rate of spinach compared to traditional methods.

4.3.6 The Blynk Notification Alert

This Plant Monitoring and Irrigation system will generate alerts for the user when a measured value exceeds the set parameter limit, utilizing IoT Blynk's server. The type of alert produced involves sending a notification to the user's smartphone app. As depicted in Figure 4.22, a soil moisture Blynk alert notification will pop up on the smartphone when the crop's soil moisture falls below 70%. Meanwhile, Figure 4.23 illustrates a water level Blynk alert notification that will pop up on the smartphone when the water level is below 40% of the water storage..

Soil Moisture 13:53
Start Watering!!

Figure 4.22 Soil Moisture Blynk Alert Notification



Water Level 13:52
Add water to tank!!

Figure 4.23 Water Level Blynk Alert Notification

4.4 Summary

Based on the results of the collected data, it can be concluded that this project successfully designed and implementated a prototype for a plant monitoring and irrigation system. The system incorporates a water tank to supply water for the crops and utilizes a modern drip irrigation system. Sensors are integrated into the system to measure crucial parameters, and the data is displayed on the user's mobile device and on an LCD in the control case for monitoring purposes. This eliminates the need for manual plant checks by the user. All the relevant parameter data is analyzed in real-time as it is collected from the sensors and transmitted through the internet via the Wi-Fi module. Additionally, the system features a solar power supply. The design of this system has been officially registered as "Design and Implementation of IoT-based Plant Monitoring System using Solar Energy".

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In In conclusion, the IoT-based plant monitoring system designed and implemented in this project proves to be a practical and dependable solution for addressing water and energy consumption issues. As outlined in the introduction, the first objective was to design and develop an IoT-based plant monitoring and irrigation system using NodeMcu ESP32, which was successfully achieved. The project focused on a small-scale crop, utilizing a hardware prototype consisting of a NodeMCU ESP32 module, a soil moisture sensor, DHT22 for monitoring surrounding conditions, an ultrasonic sensor for measuring water level in the tank, and actuators for the water pump and LCD display.

The second objective has also been successfully achieved, as the system was developed to provide real-time information on the soil moisture level and surrounding conditions, including humidity and temperature. The Blynk cloud application was effectively utilized to implement the functions set in the Blynk mobile app. The mobile application empowers users to preview the soil moisture level, water level, temperature, and humidity.

Finally, the third objective has also been successfully achieved, as evidenced in Chapter 4 by the variety of tests and experiments conducted to analyze the performance of this system. The experiments included the solar charging test, an assessment of the accuracy of temperature and humidity sensors, achieving an accuracy of 98% for temperature and 95% for the humidity sensor. Additionally, there was testing of the soil moisture sensor for the irrigation system, evaluating the water level sensor with a measurement accuracy error of only about 2% to 3%, and conducting a comparison of plant growth. The plants exhibited slightly better growth, approximately 9% to 10%, compared to traditional farming.

Overall, the system performed admirably, but its overall performance has an error of 5-10% due to sensor accuracy. Therefore, if there are any possibilities to improve the performance of this system, it would be highly recommended.

5.2 Future Works

For future improvements, design and implementation of iot based plant monitoring system using solar energy could be enhanced as follows:

I. Use a more powerful USB boost module to provide enough current for the water pump to run smoothly without affecting the power supply for nodeMCU.

II. The system cannot detect any malfunction of the sensors or actuator. This can be improved by researching ways to alert the users if any malfunctions of the sensors and actuator.

III. Research and enhance this system by integrating a component capable of monitoring plants for pests' control.

REFERENCES

[1] E. Micheni, J. MacHii, and J. Murumba, “Internet of Things, Big Data Analytics, and Deep Learning for Sustainable Precision Agriculture,” in *2022 IST-Africa Conference, IST-Africa 2022*, Institute of Electrical and Electronics Engineers Inc., 2022. doi: 10.23919/IST-Africa56635.2022.9845510.

[2] Dr. T. Veeramakali*, Dr. D. Ramkumar, Dr. S. Selvakumar, Dr. S. Pandiyan, and Dr. B. A, “Smart Agricultural Management using IoT Based Automation Sensors,” *International Journal of Recent Technology and Engineering (IJRTE)*, vol. 8, no. 6, pp. 5798–5805, Mar. 2020, doi: 10.35940/ijrte.F9073.038620.

[3] S. Fountas *et al.*, “Farm management information systems: Current situation and future perspectives,” *Comput Electron Agric*, vol. 115, pp. 40–50, Jul. 2015, doi: 10.1016/j.compag.2015.05.011.

[4] R. A. Jat, S. P. Wani, K. L. Sahrawat, P. Singh, and B. L. Dhaka, “Improving water productivity of wheat-based cropping systems in South Asia for sustained productivity. Advances in agronomy,” 2019.

[5] S. Irmak, L. O. Odhiambo, W. L. Kranz, and D. E. Eisenhauer, “Irrigation Efficiency and Uniformity, and Crop Water Use Efficiency,” 2011. [Online]. Available: https://digitalcommons.unl.edu/biosysengfacpub

[6] M. Munyaradzi *et al.*, “Precision Irrigation Scheduling Based on Wireless Soil Moisture Sensors to Improve Water Use Efficiency and Yield for Winter Wheat in Sub-Saharan Africa,” *Advances in Agriculture*, vol. 2022, 2022, doi: 10.1155/2022/8820764.

[7] A. Glória, C. Dionisio, G. Simões, J. Cardoso, and P. Sebastião, "Water Management for Sustainable Irrigation Systems Using Internet-of-Things," *Sensors*, vol. 20, no. 5, p. 1402, Mar. 2020, doi: 10.3390/s20051402.

[8] S. Wolfert, L. Ge, C. Verdouw, and M.-J. Bogaardt, "Big Data in Smart Farming – A review," *Agric Syst*, vol. 153, pp. 69–80, May 2017, doi: 10.1016/j.agsy.2017.01.023.

[9] T. M. Bandara, W. Mudiyanselage, and M. Raza, "Smart farm and monitoring system for measuring the Environmental condition using wireless sensor network - IOT Technology in farming," in *2020 5th International Conference on Innovative Technologies in Intelligent Systems and Industrial Applications (CITISIA)*, IEEE, Nov. 2020, pp. 1–7. doi: 10.1109/CITISIA50690.2020.9371830.

[10] S. S. Kanumalli, S. J. Mantena, S. Kandula, K. Doppalapudi, and T. Atluri, "Automated Irrigation Management System using IoT," in *2022 6th International Conference on Intelligent Computing and Control Systems (ICICCS)*, IEEE, May 2022, pp. 476–482. doi: 10.1109/ICICCS53718.2022.9788313.

[11] M. Mudholkar, P. Mudholkar, V. H. R. Dornadula, K. Sreenivasulu, K. Joshi, and B. Pant, "A Novel Approach to IoT based Plant Health Monitoring System in Smart Agriculture," in *2022 5th International Conference on Contemporary Computing and Informatics (IC3I)*, IEEE, Dec. 2022, pp. 113–116. doi: 10.1109/IC3I56241.2022.10072603.

[12] A. N. Matheri, F. Ntuli, J. C. Ngila, T. Seodigeng, C. Zvinowanda, and C. K. Njenga, "Renewable and Sustainable Energy Reviews," *Renewable and Sustainable Energy Reviews*, vol. 92, pp. 9–16, Sep. 2018, doi: 10.1016/j.rser.2018.04.070.

[13] P. Tricoli, M. Rinaldi, and E. R. Sanseverino, “Mini-grids, micro-grids, and energy hubs: Redefining the grid structure for the modern age. Electricity grid in 2050, 87-112.,” 2017.

[14] A. S. Ghadge, “Development and Performance Evaluation of Manually Operated Multipurpose Farm Tool,” *Indian Journal of Pure & Applied Biosciences,* vol. 8, no. 1, pp. 234–239, Feb. 2020, doi: 10.18782/2582-2845.7957.

[15] X. Wei and N. Zhang, “Current status and future trends of precision agriculture. Advances in Agricultural Machinery and Technologies, 7-27.,” 2020.

[16] R. Bongiovanni and J. Lowenberg-Deboer, “Precision Agriculture and Sustainability,” *Precis Agric*, vol. 5, no. 4, pp. 359–387, Aug. 2004, doi: 10.1023/B:PRAG.0000040806.39604.aa.

[17] C. G. Sørensen *et al.*, “Connectivity of tools, machinery, work processes and supply chains in agriculture. CIGR journal, 21(3), 156-168,” 2019.

[18] A. Mondal and P. Dutta, “Boltuino Platform Based Cognitive Irrigation System with Weather Adaptability for Efficient Water Use,” in *2022 International Conference on ICT for Smart Society (ICISS)*, IEEE, Aug. 2022, pp. 1–7. doi: 10.1109/ICISS55894.2022.9915196.

[19] H. A. Alharbi and M. Aldossary, “Energy-Efficient Edge-Fog-Cloud Architecture for IoT-Based Smart Agriculture Environment,” *IEEE Access*, vol. 9, pp. 110480–110492, 2021, doi: 10.1109/ACCESS.2021.3101397.

[20] H. Rathore, A. Ahmad, and A. Paul, “Internet of things-based smart irrigation systems: An overview on the recent trends. Sensors International, 1, 100013,” 2019.

[21] S. Basu, A. Ahmed, H. Pareek, and P. K. Sharma, “Autonomous Water Flow Control And Monitoring System,” in *2022 Interdisciplinary Research in Technology*

and Management (IRTM), IEEE, Feb. 2022, pp. 1–4. doi: 10.1109/IRTM54583.2022.9791534.

[22] A. Munir, Y. Nakamura, and A. El Saddik, “Animal and Livestock Internet of Things for Smart Agriculture. In Internet of Things for Smart Agriculture (pp. 9-31). Springer,” 2021.

[23] J. Sarker, S. Hossen, R. Ahmmed, A. Kabir, T. Hossain, and H. Ali, “Wireless Sensor Network based Sustainable Cattle Farm Feed Management and Monitoring System using Internet of Things,” in *2022 IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT),* IEEE, Jul. 2022, pp. 1–4. doi: 10.1109/CONECCT55679.2022.9865698.

[24] E. M. Ouafiq, R. Saadane, and A. Chehri, “Data Management and Integration of Low Power Consumption Embedded Devices IoT for Transforming Smart Agriculture into Actionable Knowledge,” *Agriculture*, vol. 12, no. 3, p. 329, Feb. 2022, doi: 10.3390/agriculture12030329.

[25] A. Bouyedda, B. Barelaud, and L. Gineste, “Design and Realization of an UHF Frequency Reconfigurable Antenna for Hybrid Connectivity LPWAN and LEO Satellite Networks,” *Sensors,* vol. 21, no. 16, p. 5466, Aug. 2021, doi: 10.3390/s21165466.

[26] V. K. Quy *et al.*, “IoT-Enabled Smart Agriculture: Architecture, Applications, and Challenges,” *Applied Sciences*, vol. 12, no. 7, p. 3396, Mar. 2022, doi: 10.3390/app12073396.

[27] I. Journal, “Sustainable Irrigation for Enhancing the Water usability in Agriculture using IOT,” *INTERANTIONAL JOURNAL OF SCIENTIFIC RESEARCH IN ENGINEERING AND MANAGEMENT*, vol. 04, no. 05, Jun. 2022, doi: 10.55041/ijsrem16420.

[28] H. Chowdhury, T. Chowdhury, M. S. Rahman, H. Masrur, and T. Senjyu, "A simulation study of techno-economics and resilience of the solar PV irrigation system against grid outages," *Environmental Science and Pollution Research*, vol. 29, no. 43, pp. 64846–64857, Sep. 2022, doi: 10.1007/s11356-022-20339-2.

[29] S. M. HO, S. N. NG, and M. A. MUNAAIM, "Disposal method of crystalline silicon photovoltaic panels: A case studies in malaysia," *Asian Journal of Chemistry*, vol. 33, no. 6, pp. 1215–1221, Jun. 2021, doi: 10.14233/ajchem.2021.23105.

[30] S. S. Kanumalli, S. J. Mantena, S. Kandula, K. Doppalapudi, and T. Atluri, "Automated Irrigation Management System using IoT," in *2022 6th International Conference on Intelligent Computing and Control Systems (ICICCS)*, IEEE, May 2022, pp. 476–482. doi: 10.1109/ICICCS53718.2022.9788313.

[31] S. Turaka, P. Pavani, P. Yamini, P. V. Madhavi, C. Venkateswari, and P. S. Nandini, "IoT Based Plant Monitoring System Using NODEMCU," 2022. [Online]. Available: www.questjournals.org

[32] C. S. Santiago Jr*., J. A. V. Murray, and S. Dizon, "Plant Monitoring System for Vegetable Growers," *International Journal of Recent Technology and Engineering (IJRTE)*, vol. 8, no. 6, pp. 3097–3100, Mar. 2020, doi: 10.35940/ijrte.F8393.038620.

[33] P. Bhardwaj, A. Srivastava, A. K. Pandey, A. Singh, and B. Tripathi, "IoT Based Smart Agriculture Aid System using Raspberry Pi," *Int J Eng Adv Technol*, vol. 10, no. 5, pp. 274–278, Jun. 2021, doi: 10.35940/ijeat.E2767.0610521.

APPENDICES

Appendix A Gantt Chart

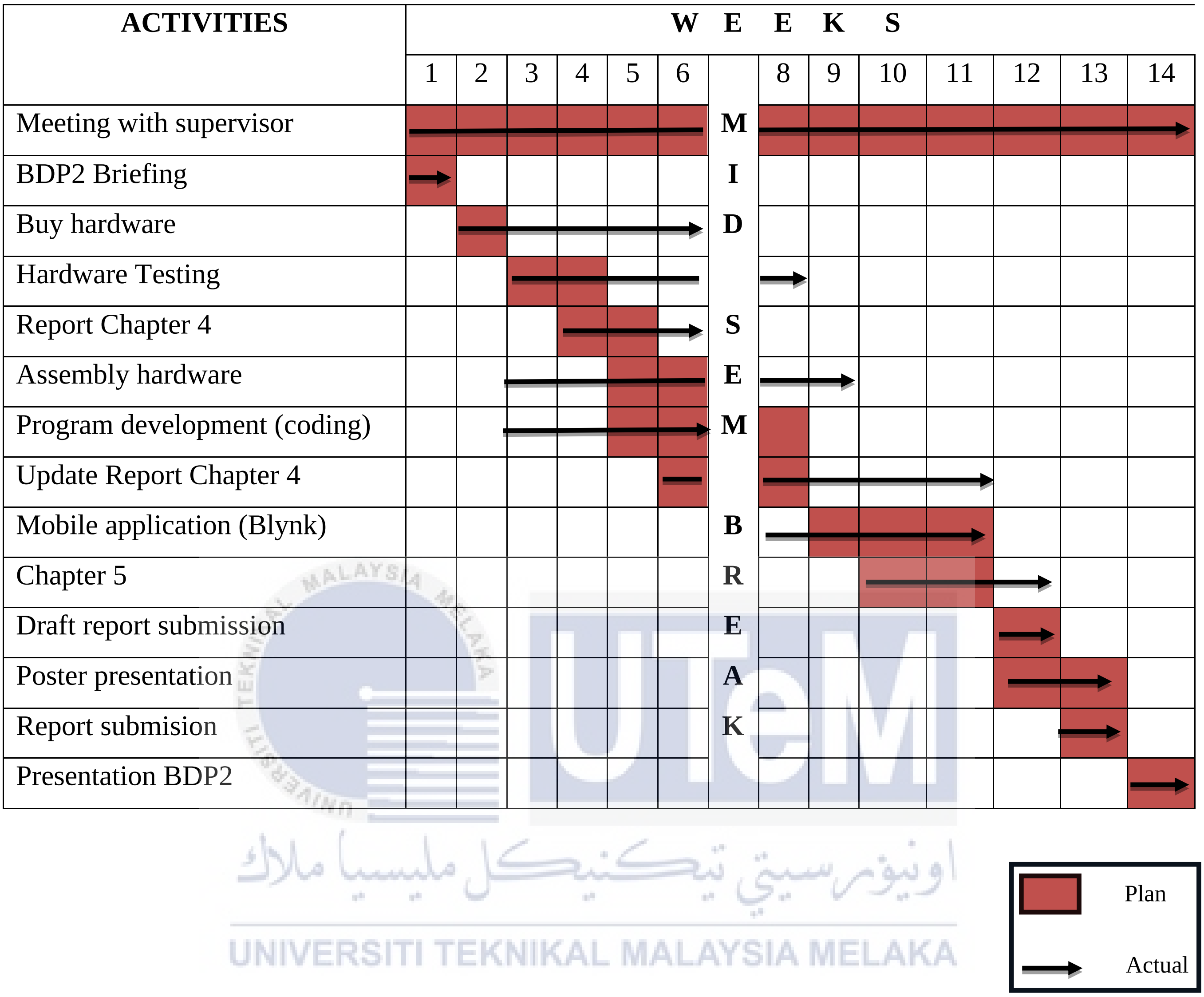
BDP 1 GANTT CHART

ACTIVITIES	W	E	E	K	S										
	1	2	3	4	5		6	8	9	10	11	12	13	14
Meeting with supervisor	🟥→	🟥→	🟥→	🟥→	🟥→	M	🟥→	🟥→	🟥→	🟥→	🟥→	🟥→	🟥→	🟥→
BDP1 Briefing	🟥→					I								
Finalize project title selection		🟥→				D								
Read journal and article			🟥→	🟥→	🟥→		🟥→	🟥→	→					
Report Chapter 1				🟥→	🟥→	S	→	→						
Flow chart for the project					🟥→	E	🟥→							
Block diagram for the project					🟥→	M	🟥→							
Report Chapter 2 & 3					🟥→		🟥→	🟥→	🟥→	→	→			
Finalize component used						B			🟥→					
Report Chapter 4 & 5						R			🟥→	🟥→	🟥→	→	→	
Draft report submission						E						🟥→		
Slide presentation						A						🟥→	🟥→	
Report submision						K							🟥→	
Presentation BDP1														🟥→

🟥 Plan

→ Actual

BDP2 GANTT CHART



ACTIVITIES	WEEKS													
	1	2	3	4	5	6		8	9	10	11	12	13	14
Meeting with supervisor	🟥 →	🟥 →	🟥 →	🟥 →	🟥 →	🟥 →	**M**	🟥 →	🟥 →	🟥 →	🟥 →	🟥 →	🟥 →	🟥 →
BDP2 Briefing	🟥 →						**I**							
Buy hardware		🟥 →	→	→	→	→	**D**							
Hardware Testing			🟥 →	🟥 →	→	→		→						
Report Chapter 4				🟥 →	🟥 →	→	**S**							
Assembly hardware			→	→	🟥 →	🟥 →	**E**	→	→					
Program development (coding)			→	→	🟥 →	🟥 →	**M**	🟥						
Update Report Chapter 4						🟥 →		🟥 →	→	→	→			
Mobile application (Blynk)							**B**	→	🟥 →	🟥 →	🟥 →			
Chapter 5							**R**			🟥 →	🟥 →	→		
Draft report submission							**E**					🟥 →		
Poster presentation							**A**					🟥 →	🟥 →	
Report submision							**K**						🟥 →	
Presentation BDP2														🟥 →

🟥 Plan

→ Actual

Appendix B Coding

```
#define BLYNK_TEMPLATE_ID "TMPL6XXCgbPjO"
#define BLYNK_TEMPLATE_NAME "TEST"
#define BLYNK_AUTH_TOKEN "nB-QYLobWCQ3kmW3UrmNk_ViD9Ev3f4R"
#define BLYNK_PRINT Serial

#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include <DHT.h>

#define DHT_PIN 13   // Pin connected to the DHT22 sensor
#define DHT_TYPE DHT22
#define relay 17
#define TRIG_PIN 26  // Pin connected to the TRIG pin of the ultrasonic sensor
#define ECHO_PIN 25  // Pin connected to the ECHO pin of the ultrasonic sensor
#define SOIL_MOISTURE_PIN 34

LiquidCrystal_I2C lcd(0x27, 16, 2);

DHT dht(DHT_PIN, DHT_TYPE);

BlynkTimer timer;

char ssid[] = "WifiHauz-2.4ghz@unifi";
char pass[] = "Mamalmol";

// Define the maximum depth of the water tank (in centimeters)
const int depth = 26;


void setup() {
  Serial.begin(115200);
  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);
  pinMode(DHT_PIN, INPUT);
  pinMode(SOIL_MOISTURE_PIN, INPUT);
  pinMode(TRIG_PIN, OUTPUT);
  pinMode(ECHO_PIN, INPUT);
  pinMode(relay, OUTPUT);
  digitalWrite(relay, LOW);
  dht.begin();
  Wire.begin(21, 22);
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.init();
  lcd.print("PLANT MONITORING");
  lcd.setCursor(0,1);
  lcd.print("& IRRIGATION SYS");
```

```
  delay(2000);


  timer.setInterval(1000L, soilMoisture);
  timer.setInterval(2000L, DHTsensor);
  timer.setInterval(3000L, waterlevel);

}

BLYNK_WRITE(V1) {
  int relayState = param.asInt();
  if (relayState == HIGH || relayState == LOW) {
    digitalWrite(relay, relayState);
  } else {
    Serial.println("Invalid relay state");
  }
}

void DHTsensor() {
  float humi = dht.readHumidity();
  float tempC = dht.readTemperature();
  float tempF = dht.readTemperature(true);

  if (isnan(tempC) || isnan(tempF) || isnan(humi)) {
    Serial.println("Failed to read from DHT22 sensor!");
  } else {
    Blynk.virtualWrite(V2, tempC);
    Blynk.virtualWrite(V3, humi);

    lcd.init();
    Serial.print("Humidity: ");
    Serial.print(humi);
    Serial.print("%");

    lcd.setCursor(0, 0);
    lcd.print("Temp : ");
    lcd.print(tempC);
    lcd.print(" C ");

    lcd.setCursor(0, 1);
    lcd.print("Humi : ");
    lcd.print(humi);
    lcd.print(" % ");

    Serial.print("  |  ");

    Serial.print("Temperature: ");
    Serial.print(tempC);
    Serial.print("°C");
  }
```

```
  delay(2000);
}

void soilMoisture() {
  int value = analogRead(SOIL_MOISTURE_PIN);
  value = map(value, 1450, 4095, 0, 100);
  value = (value - 100) * -1;

  Blynk.virtualWrite(V0, value);
  Serial.println(value);

  lcd.setCursor(0, 0);
  lcd.print("SoilMoist: ");
  lcd.print(value);
  lcd.print(" %    ");

  if (value >= 80) {
    lcd.setCursor(0, 1);
    lcd.print("S.Moist: High       ");
    Serial.println("SoilMoisture : High");
  } else if (value <= 40) {
    lcd.setCursor(0, 1);
    lcd.print("S.Moist: Low        ");
    Serial.println("SoilMoisture : Low");
    Blynk.logEvent("Attention: Soil moisture is low!");
  } else {
    lcd.setCursor(0, 1);
    lcd.print("S.Moist: Medium      ");
    Serial.println("SoilMoisture : Medium");
  }
  delay(2000);
}

void waterlevel() {
  digitalWrite(TRIG_PIN, LOW);
  delayMicroseconds(2);
  digitalWrite(TRIG_PIN, HIGH);
  delayMicroseconds(10);
  digitalWrite(TRIG_PIN, LOW);

  long t = pulseIn(ECHO_PIN, HIGH);
  long cm = t / 29 / 2;

  Serial.print("  |  ");
  Serial.print("Water Level: ");
  Serial.print(cm);
  Serial.println(" cm ");

  // Print on LCD
  lcd.init();
```

```
  lcd.setCursor(0, 0);
  lcd.print("Water Lvl: ");
  lcd.print(cm);
  lcd.print(" cm");

  // Determine water level conditions
  if (cm < 20) {
    lcd.setCursor(0, 1);
    lcd.print("Condition: High");
  } else if (cm < 10) {
    lcd.setCursor(0, 1);
    lcd.print("Condition: Med");
  } else {
    lcd.setCursor(0, 1);
    lcd.print("Condition: Low");
  }

  long level = depth - cm;
  if (level < 0)
    level = 0;

  level = map(level, 0, depth - 3, 0, 100);
  Blynk.virtualWrite(V5, level);

  delay(2000);
}

void loop() {
  Blynk.run();
  timer.run();
}
```