Faculty of Electrical Technology and Engineering

DEVELOPMENT OF SOLAR-POWERED HYDROPONIC SYSTEM USING BLYNK APP

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Bachelor of Electrical Engineering Technology (Industrial Power) with Honours

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DEVELOPMENT OF SOLAR-POWERED HYDROPONIC SYSTEM USING BLYNK APP

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A project report submitted
in partial fulfillment of the requirements for the degree of
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DEDICATION

This project is dedicated to my beloved parents, Ahmad Ma'aruff Bin Abdullah and Noriza Binti Abdullah, whose unconditional love, sacrifices, and unwavering support have been my greatest source of strength. Thank you for always believing in me, guiding me through challenges, and inspiring me to strive for excellence. Your encouragement and prayers have been the foundation of my success, and I am forever grateful for everything you have done for me.

To my esteemed lecturer, Madam Kamilah Binti Jaafar, I express my heartfelt gratitude for your invaluable guidance and support throughout this project. Your expertise, patience, and encouragement have been instrumental in shaping my work and helping me achieve this milestone. Thank you for always being approachable and for pushing me to realize my potential.

To my siblings and friends, I am deeply thankful for your constant support, companionship, and understanding. Your encouragement and the moments of joy we shared have kept me motivated and grounded throughout this journey. Thank you for being there for me during the highs and lows, and for always believing in my abilities.

Finally, I dedicate this achievement to myself. I want to thank myself for believing in my abilities, for working tirelessly, and for staying committed even on the most challenging days. I am proud of myself for never giving up, for giving more than I receive, and for always striving to make the right choices. Most importantly, I am grateful to myself for staying true to who I am and for persevering through it all.

ABSTRACT

The solar-powered hydroponic system integrated with the Blynk app represents a significant advancement in modern agriculture by combining renewable energy, precision farming, and IoT technology. Utilizing the Nutrient Film Technique (NFT), the system efficiently circulates nutrient-rich water over plant roots, ensuring optimal growth without the need for soil. Powered by solar energy, it reduces environmental impact and operational costs while maintaining uninterrupted operation through efficient energy management. The ESP32 microcontroller and integrated sensors monitor key parameters such as pH, TDS, temperature, and water levels, with real-time data accessible via the Blynk app for remote monitoring and control. Over seven days of evaluation, the system demonstrated reliability, maintaining stable conditions for lettuce cultivation with consistent growth and energy efficiency. This innovative approach addresses challenges like water conservation, food security, and sustainability, making it a viable solution for small to medium-scale urban farming while contributing to environmental resilience and global food security.

ABSTRAK

Sistem hidroponik berkuasa solar yang disepadukan dengan aplikasi Blynk mewakili kemajuan ketara dalam pertanian moden dengan menggabungkan tenaga boleh diperbaharui, pertanian ketepatan dan teknologi IoT. Menggunakan Teknik Filem Nutrien (NFT), sistem ini mengedarkan air yang kaya dengan nutrien ke atas akar tumbuhan dengan cekap, memastikan pertumbuhan optimum tanpa memerlukan tanah. Dikuasakan oleh tenaga suria, ia mengurangkan kesan alam sekitar dan kos operasi sambil mengekalkan operasi tanpa gangguan melalui pengurusan tenaga yang cekap. Pengawal mikro ESP32 dan penderia bersepadu memantau parameter utama seperti pH, TDS, suhu dan paras air, dengan data masa nyata boleh diakses melalui aplikasi Blynk untuk pemantauan dan kawalan jauh. Sepanjang tujuh hari penilaian, sistem ini menunjukkan kebolehpercayaan, mengekalkan keadaan stabil untuk penanaman salad dengan pertumbuhan yang konsisten dan kecekapan tenaga. Pendekatan inovatif ini menangani cabaran seperti pemuliharaan air, keselamatan makanan dan kemampanan, menjadikannya penyelesaian yang berdaya maju untuk pertanian bandar berskala kecil hingga sederhana sambil menyumbang kepada daya tahan alam sekitar dan keselamatan makanan global.

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I would also like to thank my parents, Ahmad Ma'aruff Bin Abdullah and Noriza Binti Abdullah, for their unconditional love, sacrifices, and constant support throughout my academic journey. Your belief in me has been my greatest source of motivation, and I am truly grateful for your encouragement and care.

To my siblings and friends, thank you for your unwavering support, encouragement, and understanding. Your companionship has kept me grounded, and your words of motivation have been a source of strength during challenging times.

Finally, I would like to acknowledge all my professors, colleagues, and everyone who has contributed in any way to my academic journey. Your support, ideas, and feedback have played a significant role in shaping my knowledge and helping me achieve this accomplishment. Thank you all for your invaluable contributions.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Traditional farming practices are being redesigned to optimise productivity and reduce resource usage in an era where environmental consciousness is crucial. This creative approach revolutionises food production by fusing hydroponic farming, Internet of Things (IoT) technology, and solar energy. Taking advantage of solar energy, our technology produces clean renewable electricity through the application of solar panels, to power the entire hydroponic system. Plants are grown in a controlled environment using nutrient-rich water solutions in hydroponic, a soilless growing technique. This method reduces needed for land, conserves water and reduces the risk of a soil-borne diseases. However, the smooth integration of our system with IoT technology using blynk app is what makes it unique. Every component of the hydroponic system is continuously monitored and optimised by means of networked sensors and actuators. The best growing conditions for plants are ensured by IoT sensors, which assess vital elements like water pH, total dissolved solids (TDS), water temperature and water level. In order to maximise crop output and quality, these data are then analysed using sophisticated algorithms to automate modifications and fine-tune the environment. Additionally, farmers may manage their crops remotely using a computer or smartphone thanks to the Internet of Things (Blynk app) connectivity, which also permits remote monitoring and control. Farmers possess total sight and control over their hydroponic farm at their fingertips, enabling them to monitor nutrient levels, regulate water flow, and receive alerts for any problems. Our solar-powered hydroponics system not only benefits the environment and advances technology, but it also has real benefits for farmers. From huge commercial farms to small-scale urban gardens, it is appropriate for a variety of applications due to its scalability, minimal maintenance requirements, and modular construction.

1.2 Problem Statement

Lack of space presents a significant challenge for aspiring home farmers, especially in urban locations where space is limited. Urban agriculture has been proposed as a solution due to its high-density nature, which reduces transit costs and directly connects people to the food chain. However, small-scale farmers face numerous barriers in adopting and deploying modern farming technologies, including high costs, insufficient knowledge, and limited access to technical support and market information.

Hydroponic technology is essential for optimizing water quality, providing nutrients, and ensuring proper system monitoring. Its adoption is critical to the success of vertical farming and hydroponics, both of which can address food security, sustainability, and environmental challenges. The integration of such systems not only enhances food security (SDG 2: Zero Hunger) but also provides innovative solutions for urban areas suffering from food deserts or limited access to fresh, healthy produce.

Food security is a pressing global issue worsened by factors such as climate change, socioeconomic inequality, and disruptions like the COVID-19 pandemic. These challenges affect communities' access to nutritious food, leading to health disparities and exacerbating global hunger. By adopting solar-powered hydroponic systems, we can contribute to healthier communities by providing access to fresh, nutrient-dense food that directly addresses the negative health outcomes associated with poor diets, food insecurity, and malnutrition. These health challenges disproportionately affect marginalized communities and individuals living in food-insecure urban areas.

In addition to food security, cultural issues also play a role in agriculture. In many urban communities, traditional farming practices may be either inaccessible or not culturally embraced, especially in regions where food systems have been disrupted by industrialization and global supply chains. Introducing innovative farming methods, such as hydroponics and vertical farming, offers a culturally sensitive alternative that blends modern agricultural techniques with urban lifestyles, allowing diverse communities to reconnect with local food production in a way that is sustainable, culturally relevant, and adaptable to changing environmental conditions.

The project also promotes SDG 7: Affordable and Clean Energy, as integrating solar power into hydroponic systems supports renewable energy use in urban farming. This aligns with global sustainability goals and reduces dependency on conventional energy sources, contributing to more sustainable agricultural practices. Additionally, the use of technologies such as the Blynk app enhances remote monitoring and control, fostering efficiency and sustainability in urban farming.

The integration of vertical farming and hydroponic technology also promotes SDG 9: Industry, Innovation, and Infrastructure by fostering technological advancement in agriculture. It enables small-scale farmers to overcome barriers to resource use, empowering them to create more resilient, efficient, and sustainable food systems.

Addressing the challenges small-scale farmers face in adopting new technology is crucial for promoting sustainable farming. By integrating practices like agroecology, conservation agriculture, and renewable energy, we can support a shift toward more sustainable food systems. Solar-powered hydroponic systems can help achieve sustainable development goals (SDGs) by providing nutritious food, reducing the environmental impact of farming, and encouraging innovation. This project also helps improve health by giving communities access to fresh food, while empowering marginalized groups and promoting food security. Overall, it supports sustainability and creates a stronger, healthier society.

1.3 Project Objective

1. To design and construct a monitoring and controlling the hydroponics system by using ESP 32 microcontroller and Blynk application.
2. To develop hydroponics system powered by solar and utilizing sensors to monitor acidity or alkalinity of the water, nutrient level, water temperature and water level in the tank for optimal plant growth.
3. To analyse the performance of the hydroponics and monitoring system based on their responsiveness, effective and reliability.

1.4 Scope of Project

Hydroponics can be scaled down for use in personal gardens and homes, making it an easy and efficient way for individuals to grow their own fresh food. Leafy greens like lettuce, Bok choy and spinach can be grown using hydroponics. Hydroponics can be used in urban areas where traditional farming may not be feasible. This can include rooftop gardens, backyards, and residential areas. In disaster relief efforts, hydroponics can provide fresh food to communities affected by natural disasters or other crises. With a monitoring system in place, farmers can track and adjust various factors such as water level, pH and nutrient levels in real-time, allowing them to optimise the system for maximum efficiency and productivity. A monitoring system that notifies farmers of any issues or problems that arise, such as the water in the tank is decreasing, nutrient level not in optimist range or a spike in pH levels. This allows farmers to quickly address any issues, minimizing damage and loss. Farmers can track the performance of hydroponics systems over time using a monitoring system with data logging capability. This data can be used to optimise the system and identify patterns or trends that can help improve efficiency and productivity. With the use of IoT liked blynk app technology, a monitoring system could allow farmers to access and control the system remotely, from anywhere with internet access. By monitoring the system regularly, farmers can detect and address problems early, avoiding costly repairs and replacements.

In this paper, the purpose is to analyse and improve the existing hydroponic system in a more effective way by using current technology and monitoring systems. Solar panels in hydroponic systems work by capturing sunlight and converting it into electricity through photovoltaic cells. This electricity powers components like water pumps and other microcontroller. Excess energy is stored in batteries for use when sunlight is unavailable. Panels are placed where they receive maximum sunlight, and wiring directs the electricity to the system. By using solar power, hydroponic setups become more sustainable, reducing costs and environmental impact. The Nutrient Film Technique (NFT) in a hydroponic system known for its efficiency and simplicity in providing plants with the necessary nutrients for growth. In this system, plants are placed in channels or gutters, gently sloped to allow a thin film of nutrient-rich water to flow over their roots. This solution, stored in a reservoir, is circulated by a pump through tubing to the highest end of the channels. Gravity then returns the solution to the reservoir, creating a continuous cycle that ensures the roots receive a constant supply of nutrients and oxygen. The sensor works by sending a small electrical current through the growing medium and measuring the resistance of the current. PH sensors monitor the acidity or alkalinity of the nutrient solution. They work by measuring the concentration of hydrogen ions (H+) in the solution. PH sensors help growers adjust the pH of the nutrient solution as needed to ensure optimal plant growth. While TDS sensors measure the concentration of dissolved substances in the nutrient solution, such as minerals and salts. These sensors typically work by employing conductivity measurements. By monitoring TDS levels, growers can ensure that the nutrient solution is properly balanced, preventing nutrient deficiencies or toxicities in plants. Furthermore, Water level sensors are used to monitor the depth of the nutrient solution in the reservoir or channels of the hydroponic system. These sensors can work using various principles such as float switches, capacitance, or ultrasonic sensors. Water level sensors are used to monitor the depth of the nutrient solution in the reservoir or channels of the hydroponic system. Next is water temperature sensors in a hydroponic system ensures the water remains within the optimal range for plant health. It provides real-time data to the grower and helps maintain conditions that support maximum growth and nutrient absorption by controlling water temperature through automated systems. Lastly, is ESP32 a small device with Wi-Fi and Bluetooth, connects to sensors and actuators in a hydroponic setup. With the Blynk app, users can control and monitor their system remotely. The ESP32 gathers data from sensors like water level and pH, sending it to the app over Wi-Fi. Users can then see real-time updates on their smartphone and adjust settings as needed, like turning system on or off. Blynk also lets users log data over time for analysis. This setup makes managing a hydroponic system easy, even for beginners, with just a smartphone and the Blynk app.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review, which is frequently used in research projects and academic articles, will provide a summary of the current research on the subject in this chapter. It will be utilized to frame the research question or hypothesis, discover patterns, gaps, and contradictions in the current literature, and give background information and context for this study.

2.2 Type of Farming

2.2.1 Greenhouse Agriculture

Growing plants in a greenhouse with only soil and a regulated atmosphere is referred to as greenhouse agriculture. Additionally, greenhouse farming can enhance yields, use less pesticides and herbicides, and conserve water. Although growing vegetables in greenhouses can be profitable, it is a challenging and complicated business[1]. Cultural practices must be organized to give high yields of dependably good-quality produce, and they 24 must be founded on solid technological understanding. Automation and greenhouse monitoring are important measures developed to lower the cost of large-scale production[2]. Figure 2.1 depicts an agricultural farm that employs a greenhouse to keep pests at bay and control their growth.

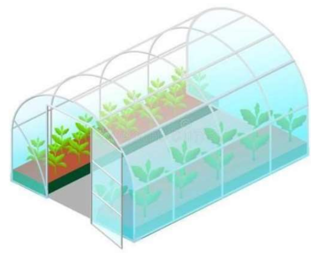

Figure 2.1 Greenhouse Agriculture

2.2.2 Hydroponic System

Instead of growing plants in a nutrient-rich solution or inert media, hydroponics is a technique for growing plants without soil[3]. The nutrients the plants' roots require to flourish are provided right to the plant while they are suspended in the solution or medium. Plants are typically grown hydroponically in a greenhouse to prevent pests. The traditional approach is less space- and water- efficient than this one. The farmer only needs to research the nutrients in the water because they could have an impact on the plant. Daily observation of the plant is required[3]. An hydroponic system's water flow is identical in that a water pump cycles water from the nutrient water tank to the grow bed and then back to the water tank. The benefit of this hydroponic system is that it may be 25 utilised to get around the issue of a decreasing amount of available land. The procedure of monitoring the quantity of plant nutrients and the pH content of the water, which must meet the needs of the plant, is crucial in a hydroponic planting system [4].

Figure 2.2 depicts a woman's hydroponic system, which includes a tank of water at the bottom and a water pump to raise the water to the grow bed, where the nutritious water meets the plant's root.

Figure 2.2 Hydroponic System

2.2.3 Aquaponic System

A hydroponics unit for growing vegetables and an aquaculture unit for raising aquatic species like fish and shellfish make up the aquaponics system. Fish and plants coexist in harmony, maximizing the usage of nutrients and minimizing the loss of precious resources like water [5]. The water is pumped from the fish tank to the grow bed with the veggies, then runs from the grow bed to the gravel filter and is collected to be pumped back to the fish tank. As a result, the fish tank is replenished with clean water. Traditional aquaculture and hydroponics are combined in the production process known as aquaponics. The quality of the water affects how well an aquaponics system works. According to 26 this theory, vegetables grow five times more quickly than they would under conventional direct soil farming because the water in fish tanks has a much higher nutritional value than regular water because it has been enriched with growing nutrients from fish waste and other chemical changes [6].

Figure 2.3 shows the aquaponic system with a varied component to sustain the system, which is the fish tank, air pump, water pump, solid filter, bio filter, and grow bed, and the system is always recycling.

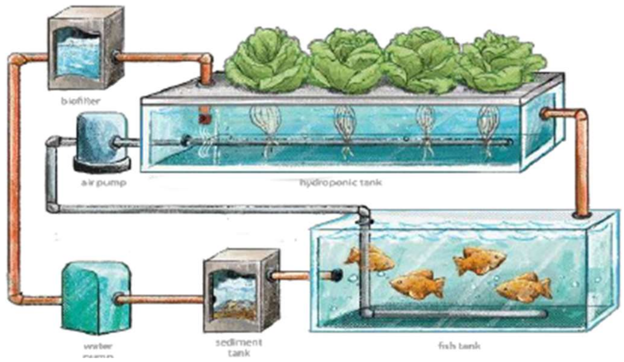

Figure 2.3 Aquaponic System

2.2.4 Aeroponic System

Aeroponics is a method of growing plants in an air or mist environment without the use of soil or another growing medium. The roots of the plant are suspended in the air and periodically misted or sprayed with a nutrient solution. This farming system empowered the producer to precisely control root zone nutrients, water regimes, and environmental conditions and have complete access to the roots throughout the life of the crop [7]. Aeroponics is considered one of the most efficient and least wasteful forms of hydroponics because it uses less water and nutrient solution than other methods. The roots are exposed to the air, so they receive more oxygen, which can lead to faster growth [7]. Aeroponic 27 systems are ideal for farming on the International Space Station.

Figure 2.4 depicts an aeroponic system; at the time of the figure's presentation, nutrient solution was being spread to the plant's root via mist tubes powered by a water pump.

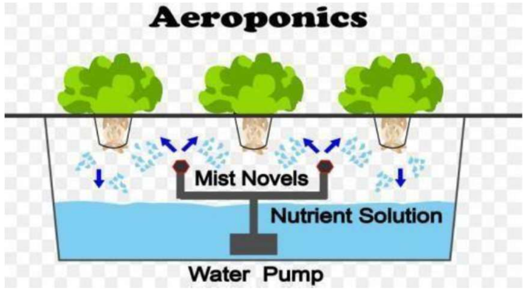

Figure 2.4 Aeroponic System

2.2.5 Table Comparison Types of Farming

Table 2.1 shows the comparison between four types of farming: greenhouse agriculture, hydroponics, aquaponics and aeroponics, with a comment.

Table 2.1 Various Types of Farming Comparison

Type of Farming	**Greenhouse Agriculture**	**Hydroponic System**	**Aquaponic System**	**Aeroponic System**
Method	Greenhouse are controlled rooms where physical inspection of plant is done with timely control of temperatures, limiting the quantity of pesticides and fertilisers required for cultivation with proper observation and testing [1].	Hydroponics is one of the farming methods without soil, but it uses water that contains nutrition. System NFT uses nutrient solutions to drain the root area [2].	Aquaponics is a way of farming that grows plants and raises fish together in a special system. Fish waste provides food for the plants, and the plants clean the water for the fish. It's like a natural recycling system where both fish and plants help each other grow [6].	An aeroponics is a method of growing plants by suspending them from a ring and exposing their roots to an airy environment; plants grow without soil or other growing medium by using nutrient solution recirculation [7].

Type of Farming	Greenhouse Agriculture	Hydroponic System	Aquaponic System	Aeroponic System
Comment	Need to use a very big greenhouse to do farming and use a lot of space and water.	It is necessary to use fertiliser that dissolves in water and to monitor the nutrition of the water 24 hours a day	Plant and raises fish needs to carefull attention to keep everything healthy and balanced.	High expenses and hard maintenance because of the technology. Suitable for the international space station.

Each style of farming has unique benefits and drawbacks, as seen in Table 1. Planting larger, heavier trees is more suited to greenhouse agriculture. Because hydroponics feed trees with water fertilizer, it is appropriate for simpler gardening. Next is hydroponics and fish that combine to be aquaponics. Last but not least, handling the aeroponics necessary for cultivation in outer space or on other planets with limited room requires highly skilled individuals.

2.3 Plant That Can Harvest in Hydroponics System

2.3.1 Lettuce

When growing lettuce hydroponically, it's important to select suitable varieties like butterhead, loose-leaf, romaine, or iceberg. The plants should be grown in an inert growing medium like rockwool or coir, with the roots submerged in a nutrient solution specifically formulated for leafy greens. The nutrient solution needs to be carefully monitored and adjusted for proper pH which its 5.5 to 6.5 and range for electrical conductivity is 0.8 to 1.2. Providing the right amount of light (12-16 hours per day), temperature (19°C-27°C), and humidity (50-60%) is also crucial for successful hydroponic lettuce cultivation [8].

Figure 2.5 Lettuce

2.3.2 Bok Choy

Figure 2.6 shows the bok choy that has been farmed using an hydroponics system. Growing bok choy in a hydroponic system is relatively straightforward. This plant needs to spacing the bok choy plants 6-12 inches apart will give them enough room to grow without competing. The pH suitable for the bok choy is best at 6.0 to 7.0, and electrical conductivity, between 1.5 and 2.0. By following these simple steps, you can successfully grow healthy, delicious bok choy in your own hydroponic system [9].

Figure 2.6 Bok Choy

2.3.3 Spinach

Growing spinach hydroponically is a rewarding and nutritious endeavor. Spinach, packed with essential nutrients like iron, vitamins K, A, C, and folate, offers numerous health benefits. To cultivate spinach hydroponically, you can use rockwool or coconut coir as the growing medium, with germination taking around 5-10 days and maturity in about 45 days. Maintaining the optimal pH range of 6.0-7.0 and providing a well-balanced nutrient mix are key. With an electrical conductivity (EC) range of 1.8-2.3, growing spinach hydroponically is moderately easy and allows for a fresh supply of high-quality, home-grown veggies all year round [10].

Figure 2.7 Spinach

2.3.4 Table Comparison Types of Planting

Table 2.2 shows the comparison between three types of planting: lettuce, bok choy, and spinach, with a comment.

Table 2.2 Various Type of Planting Comparison

Specification	**Lettuce**[8]	**Bok Choy**[9]	**Spinach**[10]
Growth Time	30-45 days	35-50 days	30-40 days
Light Requirement	High	High	Moderate to High

Specification	**Lettuce**[8]	**Bok Choy**[9]	**Spinach**[10]
Temperature Range	19-27°C (65-80°F)	10-25°C (50-77°F)	10-25°C (50-77°F)
pH Range	5.5-6.5	6.0-7.0	6.0-7.0
Nutrient Requirement	Balanced	Balanced	High Nitrogen
Watering Frequency	Regular	Regular	Regular
Space Requirement	Moderate	Moderate	Moderate
Comment	Lettuce is popular for its fast growth and crisp texture. It requires ample light and a balanced nutrient solution.	Bok choy has a slightly longer growth period but offers a unique flavor and nutritional profile. It's versatile in cooking and requires similar conditions to lettuce.	Spinach thrives in cooler temperatures and can be harvested multiple times. It's rich in nutrients, particularly iron, and grows well in hydroponic setups with sufficient nitrogen levels.

According to table 3, In a hydroponic system, lettuce, bok choy, and spinach each have distinct characteristics. Lettuce boasts a rapid growth cycle of 30-45 days, requiring high light and a balanced nutrient solution[8]. Bok choy, with a growth period of 35-50 days, demands similar conditions to lettuce but offers a unique flavor profile and moderate yield[10]. Spinach, thriving in cooler temperatures and a pH range of 6.0-6.5, has a shorter growth cycle of 30-40 days, high nitrogen needs, and yields rich, nutritious leaves suitable for multiple harvests[9]. Despite their differences, all three greens can flourish in hydroponic setups with appropriate care.

2.4 Hydroponics System Method

2.4.1 Wick System

The hydroponic wick system is a simple and low-maintenance way to grow plants without soil. It uses absorbent wicks to passively draw nutrient solution from a reservoir up to the plant roots through capillary action, eliminating the need for pumps or other active components [3].

Figure 2.8 show that wick systems work best for small, less water-demanding plants like herbs and leafy greens, making them a great choice for beginners or those with limited space. While they have some limitations compared to more complex hydroponic setups, the wick system is an easy and affordable way to get started with hydroponics.

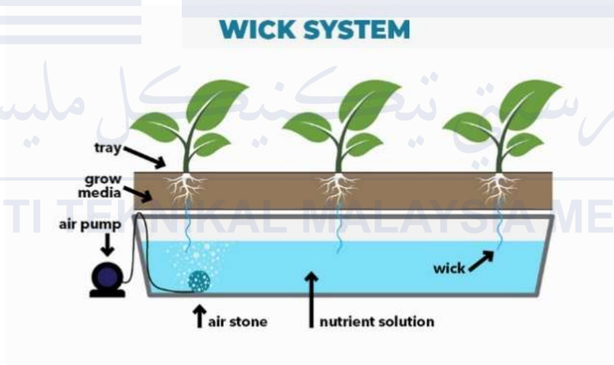

Figure 2.8 Wick System

2.4.2 Deep Water Culture

The DWC technique involves growing plants with their roots immersed in a nutrient-rich water solution. To oxygenate the water and maintain the health of the roots, air pumps and air stones are utilised. Hydroponics frequently uses DWC because it is easy to set up, maintain, and is appropriate for a variety of crops[11].

Figure 2.9 depicts the Deep Water Culture (DWC) method used in hydroponics, which uses a Styrofoam sheet to float the plant on the water and expose the root to the water with water oxidation by the air pump.

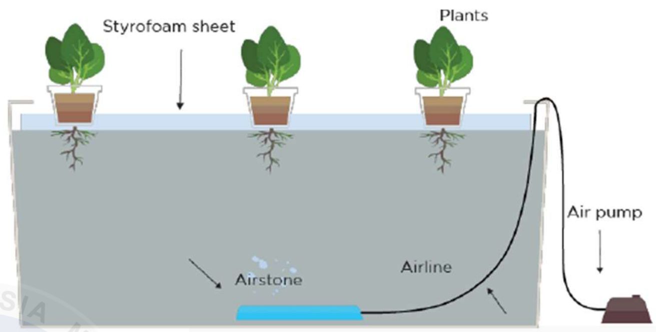

Figure 2.9 Deep Water Culture (DWC)

2.4.3 Nutrient Film Technique (NFT)

NFT is a continually flowing thin layer of nutrient-rich water that supports plant roots in a channel. A pump and air stone are used to recirculate and oxygenate the water. NFT is frequently utilised in industrial hydroponics system due to its high plant density and water-use efficiency[12].

Figure 2.10 depicts the Nutrient Film Technique (NFT) used in hydroponics system, showing how water from the water tank is pumped into the NFT, meets the root, and then returns to the water tank where the air pump blows oxygen into the water.

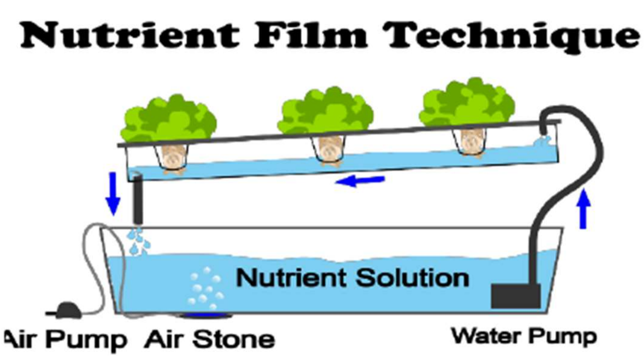

Figure 2.10 Nutrient Film Technique (NFT)

2.4.4 Table Comparison Method for Hydroponic System

Table 2.3 shows the comparison between three types of method for hydroponic system: wick system, deep water culture (DWC) and nutrient film technique (NFT) with a comment.

Table 2.3 Various Types of Method Comparison for Hydroponics

Method	**Wick System**	**Deep Water Culture (DWC)**	**Nutrient Film Technique (NFT)**
Description	Passive system where nutrient solution is drawn up to the roots via a wick material[3]	Plants suspended in a nutrient-rich solution with roots directly submerged[11]	Nutrient solution continuously flows over the roots in a shallow channel[3], [12]
Complexity	Low	Low	Moderate to High
Setup Cost	Low	Low	Moderate
Maintenance	Low	Moderate	Moderate
Oxygenation	Limited	High	Moderate
Root Support	Limited support for larger plants	Full immersion in nutrient solution	Exposed roots in the nutrient film
Nutrient Delivery	Slow	Rapid	Continuous
Suitable Plants	Herbs, Lettuce, and other small plants	Most leafy greens, herbs, and some vegetables	Most leafy greens and herbs
Comment	The wick system is simple and low-cost, suitable for small-scale	DWC provides ample oxygenation to roots but requires more maintenance to	NFT offers efficient nutrient delivery and oxygenation but requires

Method	Wick System	Deep Water Culture (DWC)	Nutrient Film Technique (NFT)
	setups and beginners. However, it may struggle to support larger plants due to limited nutrient delivery.	prevent algae growth and ensure proper nutrient levels. It's ideal for a wide range of plants, especially those with large root systems.	careful monitoring of nutrient levels and pH. It's best suited for plants with shallow root systems and can be highly productive with proper management.

The wick system, deep water culture (DWC), and nutrient film technique (NFT) are three common methods used in hydroponic gardening, each with distinct features and considerations. The wick system is simple and low-cost, ideal for beginners and small-scale setups, but may struggle with larger plants due to slow nutrient delivery[12]. DWC provides excellent oxygenation to roots but requires more maintenance to prevent algae growth and ensure proper nutrient levels; it suits a wide range of plants, especially those with large root systems[11]. NFT offers efficient nutrient delivery and oxygenation, but demands careful monitoring of nutrient levels and pH; it's best suited for plants with shallow root systems and can be highly productive with proper management[13].

2.5 Water Quality Parameter

2.5.1 Water Specification

The utilised water must be pure and devoid of any chemical or biological impurities. The pH range that the system typically requires to planting lettuce is between 5.5 to 6.5 and not forget range for electrical conductivity, between 1.5 and 2.0. The water should be at a temperature that is appropriate for the lettuce. For instance, lettuce require water temps between 19 to 27°C, and humidity 50 to 60 percent. The water should contain the correct amount of dissolved oxygen and other nutrients for the plants. Regular testing of the hydroponics system water is required to make sure that parameter is within the desired range[8].

2.5.2 Ph Up and Ph Down Solution

pH Up and pH Down solutions are essential tools used to adjust the pH levels of water or nutrient solutions in various applications, such as hydroponics and aquariums. pH Up solutions typically contain bases like potassium hydroxide (KOH) and potassium carbonate (K2CO3), which are used to raise the pH level, making the solution more alkaline. This adjustment is crucial for maintaining the optimal pH range (usually between 5.5 and 6.5) for nutrient uptake in plants and the health of aquatic life. Conversely, pH Down solutions contain acids such as phosphoric acid (H3PO4) and are used to lower the pH level, making the solution more acidic. Proper pH management ensures that plants can absorb nutrients efficiently and that fish and other aquatic organisms thrive in a stable environment. Both types of solutions should be added in small increments, with frequent pH measurements to avoid drastic changes, and handled with care due to their corrosive nature.

Figure 2.11 Ph Up and Ph Down Solution

2.5.3 Nutrient A and Nutrient B

In a hydroponic system for growing lettuce, the nutrient solution is typically divided into two parts, nutrient A and nutrient B, to prevent the formation of insoluble precipitates that could hinder nutrient availability for the plants.

Nutrient A typically contains the macronutrients nitrogen (N), phosphorus (P), and potassium (K), as well as secondary nutrients like calcium (Ca) and magnesium (Mg)[8]. The recommended concentrations for a hydroponic lettuce system are:

- Nitrogen (N): 100-200 ppm
- Phosphorus (P): 30-60 ppm
- Potassium (K): 100-250 ppm
- Calcium (Ca): 100-200 ppm
- Magnesium (Mg): 50-100 ppm

Nutrient B contains the micronutrients such as iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), boron (B), and nickel (Ni) in trace amounts[8]. These micronutrients are essential for various enzymatic processes and overall plant health.The two-part nutrient system ensures the nutrients remain soluble and available for the plants to absorb, as mixing certain nutrients like calcium and sulfates can lead to the formation of insoluble precipitates. Growers must carefully measure and mix the two parts in the proper ratios to provide a balanced nutrient solution for optimal lettuce growth[8].

Figure 2.12 Nutrient A and Nutrient B

2.6 Type of Microcontroller

Microcontroller acts as the central brain, responsible for collecting data, processing it, and enabling communication between different components. The microcontroller interfaces with sensors to gather crucial information about the solar power system, such as solar panel performance, battery status and environmental conditions. Next, the microcontroller can perform basic calculations on the collected data such as energy generation by the solar panel over time and battery health and remaining capacity.

Then, the microcontroller acts as a communication hub, facilitating interaction between different parts of the system. For example, sensor, server, display unit and control unit. Overall, the microcontroller plays a critical role in transforming a collection of sensors and a data logger into a functional solar power monitoring system.

2.6.1 ESP32 Wroom

The ESP32 is a strong and adaptable microcontroller that can be used in Internet of Things applications since it has integrated Bluetooth and Wi-Fi connectivity. Complex programming jobs can be accomplished with its sufficient processing power and memory[13]. Here's how to use your hydroponic system with the ESP32:

- TDS/EC Control : By integrating a TDS sensor with an ESP32 microcontroller, we can create a smart and automated hydroponic system that continuously monitors and maintains the nutrient concentration in the nutrient solution, ensuring healthy plant growth and maximizing crop yields.
- pH Level Control: Similar to the Arduino, the ESP32 has the ability to use a sensor to measure pH and activate alkaline or acidic dosing systems to change the pH. In order to keep the pH range within the intended range, it can retain calibration data and use algorithms.
- Water Level Monitoring and Control: To keep an eye on the water level in the tank, the ESP32 can communicate with water level sensors. It can activate valves or pumps to add or remove water as needed to keep the ideal water level.
- Notifications: When any parameter surpasses the predetermined thresholds, the ESP32 has the ability to send notifications to your phone application. It may use a variety of Wi-Fi networks to connect to the internet.

Because of its connectivity, the ESP32 can be used to remotely monitor and manage an hydroponic system. Through communication with cloud platforms, data logging, analysis, and remote system access are made possible. Remember that switching from Arduino Mega to ESP32 would mean modifying your code and making sure that it works with the development environment of the ESP32, which includes the ESP-IDF framework and the Arduino IDE[13].

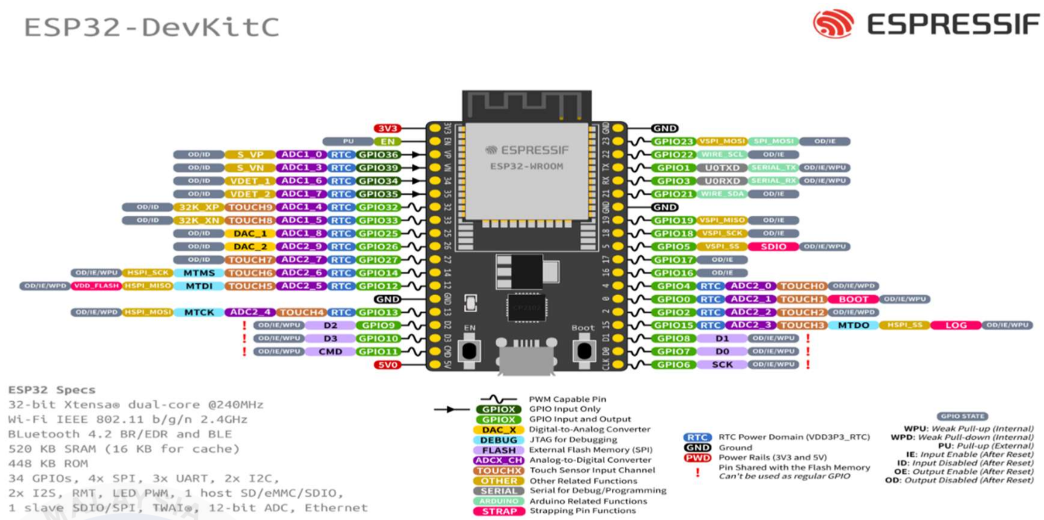

Figure 2.13 ESP32

2.6.2 Node MCU Wi-Fi Module (ESP-8266)

ESP8266 is a low-cost, low-power Wi-Fi module that is commonly used in IoT projects and can be used in hydroponic systems to connect the microcontroller to the internet. This allows the system to be monitored and controlled remotely via mobile phone. The ESP8266 can be combined with a microcontroller (such an Arduino) in an hydroponic system to provide wireless connectivity and communication[14]. In an hydroponic system, it can be useful in the following ways:

- Remote Monitoring: You may keep an eye on the conditions and status of your hydroponic system remotely by connecting the ESP8266 to the internet. This entails keeping an eye on the temperature, pH, level, and nutrients in the water, among other crucial parameters. Using a computer or a smartphone, you can access this information from any location.
- Data Logging: Hydroponic system's ESP8266 can be configured to record data from a variety of sensors. For analysis and historical tracking, this data can be sent to a cloud platform or kept locally. It enables you to maintain track of significant information and performance patterns in your system.

- Remote Control: You may also operate several features of your hydroponic system from a distance with the ESP8266. For instance, you can use a web interface or your smartphone to change the temperature, turn on or off pumps, and alter lights. This allows you the freedom to optimise and control your system even when you're not there in person.
- Notifications and Alerts: In the event of any unusual circumstances or system failures, the ESP8266 can be configured to send notifications and alerts to your email address or cell phone. This makes sure that any problems with hydroponic system are quickly communicated to you so that you may address them right away.

All things considered, the ESP8266 offers a practical and affordable means of connecting hydroponic system to the internet so that remote monitoring and control are possible. It makes the system more accessible and functional, which makes it easier to maintain and manage[14].

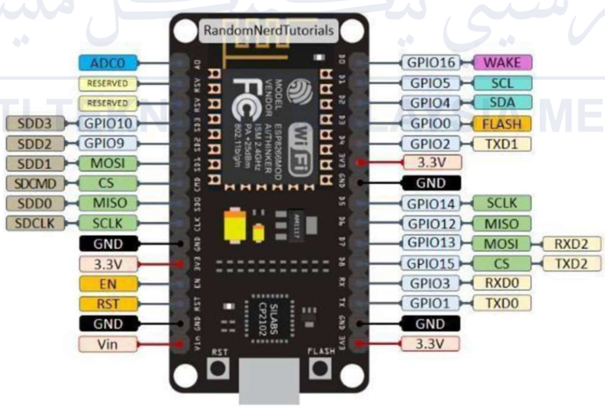

Figure 2.14 ESP8266 (NodeMCU)

2.6.3 Arduino Mega

Arduino Mega can be effectively utilized in hydroponic systems for automation, monitoring, and control purposes. With its numerous digital and analog I/O pins, Arduino Mega can connect various sensors and actuators crucial for managing a hydroponic setup. For instance, sensors like pH, EC (electrical conductivity), temperature, humidity, and water level sensors can be interfaced with Arduino Mega to monitor environmental conditions and nutrient levels in the hydroponic solution[15].

Arduino Mega can also control various components such as water pumps, solenoid valves for nutrient solution distribution, air pumps for oxygenation, and grow lights. By programming Arduino Mega, users can create custom algorithms to regulate pH and EC levels by controlling chemical dosing pumps or adjusting nutrient solution concentration. Additionally, Arduino Mega can automate tasks such as scheduling irrigation cycles or adjusting lighting schedules based on plant growth stages or environmental conditions.

Overall, Arduino Mega offers the flexibility and capability required to build and customize sophisticated automation systems for hydroponics, empowering users to optimize plant growth, conserve resources, and enhance overall productivity in hydroponic setups[15].

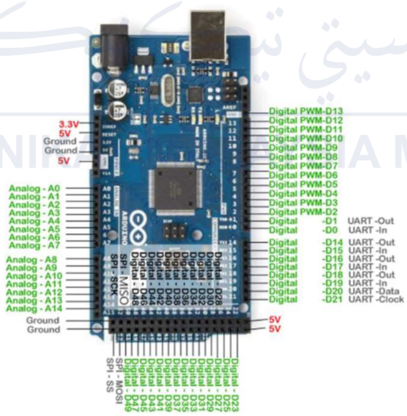

Figure 2.15 Arduino Mega

2.6.4 Table Comparison Types of Microcontrollers

Table 2.4 shows the comparison between three types of microcontroller: ESP32, ESP8266 (NodeMCU), and Arduino Mega, with a comment.

Table 2.4 Various Type of Microcontroller Comparison

Specification	**ESP32**[13]	**ESP8266 (NodeMCU)**[14]	**Arduino Mega**[15]
Microcontroller	Dual-core Tensilica LX6	Tensilica L106 32-bit	ATmega2560
CPU Speed	Up to 240 MHz	Up to 80 MHz	16 MHz
GPIO	Up to 36 GPIO pins	Up to 17 GPIO pins	54 digital I/O pins
Analog Inputs	18 channels (12-bit SAR ADC)	1 channel (10-bit ADC)	16 channels (10-bit ADC)
Analog Outputs	8-bit DAC channels	None	12-bit DAC channels
Flash Memory	Up to 4 MB	Up to 4 MB	256 KB
SRAM	Up to 520 KB	Up to 50 KB	8 KB
Comments	ESP32 is a powerful microcontroller with dual cores, suitable for complex tasks and multitasking.	NodeMCU is based on the ESP-8266 microcontroller, offering simplicity and affordability for IoT projects.	Arduino Mega, powered by ATmega2560, provides ample GPIO pins and is well-suited for a wide range of projects, especially those requiring numerous I/O connections.

The table compares ESP32, NodeMCU (ESP-8266), and Arduino Mega. ESP32 boasts dual-core processing with Wi-Fi and Bluetooth, while NodeMCU offers single-core processing and Wi-Fi only. Arduino Mega lacks wireless capabilities but provides a high number of I/O pins. ESP32 and NodeMCU operate at 3.3V, while Arduino Mega runs at 5V. Programming options vary, with ESP32 and NodeMCU supporting Arduino IDE and more, while Arduino

Mega primarily uses Arduino IDE. Prices range from moderate to high for ESP32, low to moderate for NodeMCU, and moderate for Arduino Mega.

2.7 Past Studies

A literature review will analyse and evaluate existing research within related to the project, summarizing the main points and evaluating the contribution to the area of study.

Table 2.5 The Comparison Between Past Studies That Related to The Project

No.	Title	Author Name	Statement/Technique	Remark	Finding
1	Greenhouse Vegetable Production-General Information and Bibliography[1]	Hunter Johnson, Jr.	Producing greenhouse-grown vegetables can be profitable, but it is a difficult and complex enterprise. Cultural methods must be based on sound technical knowledge and planned to produce high yields of consistently top-quality produce.	Provides general information and an extensive bibliography for commercial greenhouse vegetable production in California.	Greenhouse vegetable production requires solid technical knowledge to achieve high yields and top-quality produce, with complex cultural methods.
2	IOT Based Smart Greenhouse Automation Using Arduino[2]	Prof. D.O.Shirsath, Punam Kamble, Rohini Mane, Ashwini Kolap	Proposed system allows remote monitoring and control of greenhouse environment using IoT	Automates greenhouse environment control to optimize plant growth. Eliminates need for constant human monitoring and intervention	Automates greenhouse environment control to optimize plant growth, eliminating the need for constant human monitoring and intervention.
3	Monitoring And Controlling Smart Hidroponics Using Android	Ivan Sheva Muhammad Firdaus, Mohammad Rizalul Fikr, Mia Rosmiati	Peristaltic pump and water pump used to automatically adjust nutrient levels and pH.	Automates monitoring and control of key hydroponic parameters. Eliminates	The system automates hydroponic parameters, allowing remote

No.	Title	Author Name	Statement/Technique	Remark	Finding
	and Web Application[4]		NodeMCU used for wireless communication to send sensor data to Firebase database. Sensor data displayed in real-time on web and Android applications.	need for manual intervention to maintain optimal growing conditions. Allows remote monitoring and control via web and mobile apps.	control and monitoring of nutrient levels, pH, and other key factors.
4	Sustainable Development Using Renewable Energy to Boost Aquaponics Food Production in Needy Communities[5]	Fareed Ismail, Em. Prof. Jasson Gryzagoridis	Integration of renewable energy sources (solar and wind power) into aquaponics systems can significantly boost food production in needy communities.	can improve food security and reduce carbon emissions, making it a sustainable approach to address global food security challenges.	Integrating renewable energy sources into aquaponics systems can improve food security and reduce carbon emissions in needy communities.
5	IoT Enabled Aquaponics with Wireless Sensor[6]	Praveen C Menon	IoT enabled aquaponics system with wireless sensors for real-time monitoring of water quality, pH, ammonia, and nitrite levels.	Sustainable aquaculture through efficient water usage and monitoring.	The IoT-enabled aquaponics system allows real-time monitoring of water quality and parameters, ensuring sustainable aquaculture through efficient water usage.
6	Automatic Monitoring and Control System in Aeroponic Plant Agriculture[7]	Sanjay Agrawal, Shubham Jain, Shubham Sharma, Shubham Tiwari	Developed an automatic monitoring and control system for aeroponic plant agriculture.	The system uses sensors to monitor parameters like temperature, humidity, pH, and dissolved oxygen, and automatically	The system uses sensors to maintain optimal conditions for plant growth by monitoring and adjusting parameters

No.	Title	Author Name	Statement/Technique	Remark	Finding
				adjusts them to maintain optimal conditions for plant growth.	like temperature, humidity, and pH automatically.
7	Effect of Lettuce on Different Recirculation Intervals of an IoT-Based Hydroponics System Using Deep Flow Technique[16]	Lovina Siechrist T. Agbayani, Jocelyn F. Villaverde	Developed an IoT-based monitoring system for a hydroponic setup using the Deep Flow Technique (DFT). Compared the growth and yield of lettuce with 3 different nutrient recirculation intervals: 30 mins every 1 hour, 12 hours, and 24 hours.	Lettuce with 30 min recirculation every hour (T1) had significantly higher yield, plant height, head mass, and number of leaves compared to 12 hr (T2) and 24 hr (T3) recirculation intervals. Frequent recirculation (T1) provided better nutrient availability and uptake for optimal plant growth.	Frequent nutrient recirculation (every 30 minutes) significantly improves lettuce growth, yielding better plant height, head mass, and leaf number compared to less frequent recirculation.
8	Development of Automated Monitoring System for Hydroponics Vertical Farming[9]	G W Michael, F S Tay, Y L Then	Proposed an automated monitoring system for hydroponics vertical farming to monitor and maintain nutrient solution levels, including EC, pH, liquid level, and water temperature.	The system uses an Arduino Mega microcontroller and ESP8266 NodeMCU to send data to the Ubidots Cloud. It aims to reduce water and electrical consumption while allowing remote monitoring of plant growth.	The automated monitoring system helps reduce water and electrical consumption while allowing remote monitoring of nutrient and water levels.
9	A Quantitative Analysis of Nutrient	Nuchada Maneejantra, Satoru	Spinach plants were grown hydroponically in	The study determined the minimum	The study identified minimum

No.	Title	Author Name	Statement/Technique	Remark	Finding
	Requirements for Hydroponic Spinach (Spinacia oleracea L.) Production Under Artificial Light in a Plant Factory[10]	Tsukagoshi, Na Lu, Kanyaratt Supaibulwatana, Michiko Takagaki, Wataru Yamori	a plant factory with controlled environmental conditions (temperature, light, CO_2). The macronutrient requirements were quantified at different growth stages by analyzing the nutrient concentrations in shoots and roots.	macronutrient requirements (N, P, K, Ca, Mg, S) for spinach to achieve marketable size in 12-15 days after transplanting. This knowledge can guide quantitative fertilizer management for efficient hydroponic spinach production in plant factories.	nutrient requirements for spinach, which can help optimize fertilizer management for efficient hydroponic spinach production in plant factories.
10	A Development of an Automatic Microcontroller System for Deep Water Culture (DWC)[11]	M.F. Saaid, N.A.M. Yahya, M.Z.H. Noor, M.S.A. Megat Ali	Hydroponics method of growing plants using mineral nutrient solution in water, without soil. Deep Water Culture (DWC) supplies water containing nutrients directly to the roots of the plant continuously.	The DWC system ensures roots are always submerged in water and oxygen, leading to highly oxygenated roots, less fertilizer use, low maintenance cost, and reduced monitoring time. The system also maintains water levels through level control, triggering valves to control water flow into or	The DWC system ensures optimal root oxygenation and reduces fertilizer usage and maintenance costs, making it efficient and low-maintenance.

No.	Title	Author Name	Statement/Technique	Remark	Finding
				out of the reservoir.	
11	A Survey of Smart Hydroponic Systems[3]	Falmata Modu, Adam Adam, Farouq Aliyu, Audu Mabu, Mahdi Musa	Survey of various smart hydroponic systems developed to date, categorized based on automation level, tasks automated, type of automation, and mode of control.	Provides a comprehensive overview and taxonomy of smart hydroponic systems. Explains the different techniques used in hydroponic systems.	Provides an overview of various smart hydroponic systems and categorizes them based on automation level, control methods, and other factors.
12	Prototype NFT/DFT Hydroponic Data Collection Using IoT System[12]	IGKG Puritan Wijaya ADH, I Nyoman Rudy Hendrawan, I Made Bhaskara Gautama, I Gusti Ngurah Wikranta Arsa	Developed an IoT-based system to monitor water conditions (pH, TDS, temperature, flow rate, water level) in NFT/DFT hydroponic systems using sensors and an ESP32 microcontroller. Data is transmitted via MQTT protocol to a web interface for remote monitoring.	The system was successfully implemented and tested, allowing real-time monitoring of hydroponic water conditions remotely through a website.	The IoT-based system allows remote monitoring of water conditions in hydroponic systems, improving real-time control and system management.
13	Design of a Smart Hydroponics Monitoring System using an ESP32 Microcontroller and the Internet of Things[17]	Anees Abu Sneineh, Arafat A.A. Shabaneh	Used an ESP32 microcontroller with TDS, pH, water level, and temperature sensors to build the hydroponic monitoring system. The ESP32 automatically collects and evaluates sensor data to drain	Successful implementation of a hydroponics monitoring system integrated with IoT. Allows remote monitoring and control of key parameters like pH, nutrient levels, and	The IoT-based monitoring system allows remote control and monitoring of key hydroponic parameters like pH and nutrient levels via a

No.	Title	Author Name	Statement/Technique	Remark	Finding
			water, nutrients, or salt into the plant basin as needed. Users can check parameters and control pumps remotely via the Blynk IoT app on a smartphone.	temperature. Helps optimize plant growth conditions and prevent crop losses.	smartphone app.
14	Development of Smart Hydroponic System using Internet of Things[18]	Anis Abdul Hayu, Mariyam Jamilah Homam	The system uses IoT technology to monitor and control temperature, humidity, water levels, and pH levels in a hydroponic setup. Sensors are used to actively monitor these parameters, with automatic controls like water pumps, fans, and pH level displays on a Blynk app to maintain optimal conditions for plant growth.	The smart hydroponic system integrates IoT capabilities to improve agricultural efficiency and productivity. It provides a practical solution and effective alternative to modern farming methods. However, challenges like cost, maintenance, and user training need to be addressed for wider adoption.	IoT technology enhances agricultural productivity by enabling real-time monitoring and control of parameters like temperature, humidity, and pH levels.
15	Greenhouse Automation Using Internet of Things in Hydroponics[19]	R B Harikrishna, Austin Anand Kumar A, Suraj R, Shanthini Pandiaraj, Paramasiva Pandi	Hydroponics is a technique in agriculture that uses minimal nutrient material to nourish plants. The project proposes to connect sensors and actuators to the UBIDOTS cloud for creating	The system focuses on monitoring temperature, humidity, luminance, water level, pH, TDS, and nutrient levels. It automates lighting, water flow, exhaust	IoT integration allows for the automation of greenhouse environmental controls such as lighting, water flow, and air circulation

No.	Title	Author Name	Statement/Technique	Remark	Finding
			a closed-loop IoT system to control the greenhouse environment.	fans, and foggers based on sensor data.	based on real-time sensor data.
16	Hydroponic and Aquaponic Farming: Comparative Study Based on Internet of things IoT technologies[20]	Ibtissame EZZAHOUI, Rachida AIT ABDELOUAHID, Khaoula TAJI, Abdelaziz MARZAK	Compares hydroponic and aquaponic farming methods using IoT technologies.	Hydroponic farming grows plants without soil, while aquaponic combines hydroponics and aquaculture to grow plants and fish together.	The study compares hydroponic and aquaponic farming methods and highlights how IoT can optimize both methods' efficiency and productivity.
17	Automated Hydroponic System with Solar Powered Battery Management System[21], [22]	A. Chandra Shaker, L. Sai Srivalli, K. Sharanya, D. Akhila, T. Madhu Chandana	This system monitors plant water level, pH level, temperature, and humidity, and uploads sensor data to the ThingSpeak cloud. It includes a battery management system with a solar panel for charging the battery. The primary controller is an Arduino UNO microcontroller running a C program.	The system successfully integrates hardware and software components for automated hydroponic plant monitoring and utilizes solar energy. It focuses on improving automation in hydroponic plant growth while considering security aspects.	The solar-powered system successfully integrates automation and sustainable energy, reducing dependency on external power sources while optimizing hydroponic plant care.
18	Smart Hydroponic Systems: Optimizing Nutrient Levels with IoT[22]	Pradnya Vishram Kulkarni, Dr. Vinaya	Comprehensive study analyzing climatic conditions and nutrients in a smart hydroponic vertical Nutrient Film Technique (NFT) setup for	Aims to elucidate significance of each parameter in optimizing plant growth by analyzing data associations.	Data analysis reveals the importance of monitoring TDS and pH levels to optimize nutrient conditions for

No.	Title	Author Name	Statement/Technique	Remark	Finding
			leafy greens. Integrates wireless sensor network and IoT using ESP32 microcontrollers for real-time monitoring of TDS, pH, and EC.	Higher TDS correlates with better spinach growth, while reduced pH harms plants. Crucial for interpreting disease symptoms and optimizing yields.	spinach growth, helping maximize yield.
19	IoT-Based Solar-powered Smart Hydroponics system with Real-Time Monitoring and Control System[23]	Ana Marie S. Ardina, Deiscart D'Mitrio C.Maceda, Christian Earl B. Borromeo, Jennifer Dela Cruz, Jodel M. Fedeluz, Airu Marcu F. Mauricio, Glenn V.Magwili, Jenette C. Centeno, Andrew Bitancor	Prototype of a smart hydroponics system that allows growing romaine lettuce in a controlled environment, integrated with IoT technology for real-time monitoring and control of pH, EC, TDS, water temperature, ambient temperature, humidity and light intensity.	Uses solar energy as main power source.	This system uses solar energy for sustainable hydroponics and enables remote monitoring and control of plant growth factors.
20	Internet of Things (IoTs) based hydroponic lettuce farming with solar panels[24]	Supachai Puengsungwan, Kamon Jirasereeamornkul	Use an IoT-based transpiration leaf sensor to monitor the internal changes of lettuce plants in real-time. Determine the suitable duty cycle for electric pumps based on the transpiration status, reducing power consumption. Install solar panels as a	Conventional methods using 30 sets of solar panels (300W and 100A-Hr each) would be required for an 800 sq.m. hydroponic farm, costing 250% of the hydroponic system cost. With the proposed IoT-based technique, only	The IoT system uses a leaf transpiration sensor to optimize water pump duty cycles, reducing power consumption while using solar energy to sustain the system.

No.	Title	Author Name	Statement/Technique	Remark	Finding
			sustainable energy source, with the number of panels optimized using the proposed IoT-based technique.	10 sets of solar panels would be needed, reducing the installation cost by 67%.	
21	Smart Internet of Things System for Hydroponic[25]	Muhammed Yusuf Mazlan, Siti Amely Jumaat	The technology combines a typical farming system with a web interface for monitoring the hydroponic system status. Sensor data is collected and analyzed on a cloud-based web page through a mobile application. LED indicators show the water nutrient level status.	This work developed a smart IoT system for hydroponics with a web and mobile interface to monitor water nutrient levels using sensors and LED indicators.	Combines IoT with a web interface to monitor and analyze the hydroponic system's nutrient levels remotely.
22	IoT-based Smart Hydroponic System Using Nutrient Film Technique (NFT) for Lettuce Plant[13]	Muhamad Zaid, Natasha Amira Abdul Rauf, Sharifah Saon, Danial Md Nor, Abd Kadir Mahamad, Shingo Yamaguchi, Mohd Anuaruddin Bin Ahmadon	The project aims to develop a smart hydroponic system using NFT with IoT integration to provide an optimum growing environment. Essential parameters like light intensity, temperature, humidity, TDS, and pH are monitored remotely through the Favoriot IoT platform.	This work developed an IoT-based smart hydroponic system using NFT to remotely monitor and control key environmental parameters for optimal lettuce growth.	The IoT system monitors and adjusts key environmenta l factors to ensure optimal conditions for lettuce growth.
23	Smart Hydroponic System Using	Badr Tarek Mohamed, Aml Mohamed Ahmed,	The paper aims to provide automatic monitoring and	This research proposed a fuzzy logic-based smart	Fuzzy logic control allows automated adjustments

No.	Title	Author Name	Statement/Technique	Remark	Finding
	Fuzzy Logic Control[14]	Abdullah Medhat Makram, Ahmed Ali Ahmed, Khloud Khaled Fouad, Ahmed Mogahed Abo-Elmagd, Yasser Kamal Omar	controlling of hydroponic plants using fuzzy logic to control the fan and water pump based on measured temperature, humidity, pH, and water level. The system uses an Arduino microcontroller, sensors, and an ESP8266 Wi-Fi module.	hydroponic system for automatic monitoring and control of key environmental parameters using sensors and actuators.	to temperature, humidity, pH, and water levels, improving system responsiveness and efficiency.
24	Design and Implementation of Nutrition Control System for Optimization of Hydroponic Plant Growth[26]	Safira Firdaus Mujiyanti, Sefi Novendra Patrialova, Maulina Kartika, Muhammad Fachmi Febrian	The method used is Arduino-based Close loop Feedback Control to adjust the output of the A/B Mix liquid fertilizer to obtain the desired TDS (Total Dissolve Solid) value for hydroponic plants. The results showed a control value TDS of 1025.73 ppm with a 2% error from the 1000 ppm setpoint.	This research developed a nutrient control system to optimize hydroponic plant growth by maintaining the desired TDS value using feedback control of liquid fertilizer output.	The nutrient control system optimizes TDS levels in hydroponics, ensuring plants receive the correct nutrients for growth with minimal error.
25	Development of Automatic Hydroponic Plant Watering Based Arduino Microcontroller [15]	Anita Susilawati, M. Abdi Mauliwarman, Dodi Sofyan Arief, Herisiswanto	The paper develops a design for an automatic hydroponic plant nutrient sprinkler using an Arduino Mega 2560 microcontroller, TDS sensor, RTC, and relay to	The device can save time and energy, making it more efficient than manual watering systems.	The automatic watering system saves time and energy by efficiently controlling the watering process, improving

No.	Title	Author Name	Statement/Technique	Remark	Finding
			control water pumps.		overall system efficiency.

2.8 Summary

Based on the literature review, the key points regarding different types of farming methods and their suitability for growing various plants in a hydroponic system.

Greenhouse agriculture provides a controlled environment for cultivation, but requires significant space and resources, Hydroponics, which grows plants in nutrient-rich water without soil, is well-suited for leafy greens like lettuce, bok choy, and spinach. Aquaponics combines hydroponics and aquaculture, allowing plants and fish to coexist in a symbiotic system. Aeroponics, which suspends plant roots in air and mists them with nutrients, is one of the most efficient hydroponic methods, but requires specialized expertise.

Within hydroponic systems, different techniques like wick systems, deep water culture, and nutrient film technique each have their own advantages and limitations in terms of complexity, cost, maintenance, and suitability for various plant types. Monitoring and controlling water quality parameters like pH, electrical conductivity, temperature, and dissolved oxygen is crucial for successful hydroponic cultivation.

The literature also highlights the use of IoT technology, such as ESP32 and NodeMCU Wi-Fi modules, to enable remote monitoring, data logging, and control of hydroponic systems by using blynk app, which can optimize efficiency and productivity. And not forget hydroponic system use renewable energy such as solar power to energise the microcontroller, sensor and water pump in the hydroponic system.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will converse about the method and description that is used to complete the project successfully. All technical sections will explain with a block of diagram and flow chart along with the development and function of software and hardware. The role of the component or software used is defined.

3.1.1 Block Diagram Hydroponic System

The block diagram from the figure 3.1 illustrates a system designed for monitoring and controlling a process using the Blynk app. The input section includes various sensors that collect data from the environment or system being monitored. This data is then processed by a microcontroller, which acts as the central processing unit. The microcontroller is powered by a dedicated power source, ensuring continuous operation.

The processed data is sent to the Blynk app, which serves as the output interface, allowing users to monitor the system in real-time. Additionally, the Blynk app provides feedback looping capabilities, enabling users to send control commands back to the microcontroller to control on and of the system. This feedback loop ensures that the system can be dynamically controlled and optimized based on real-time data.

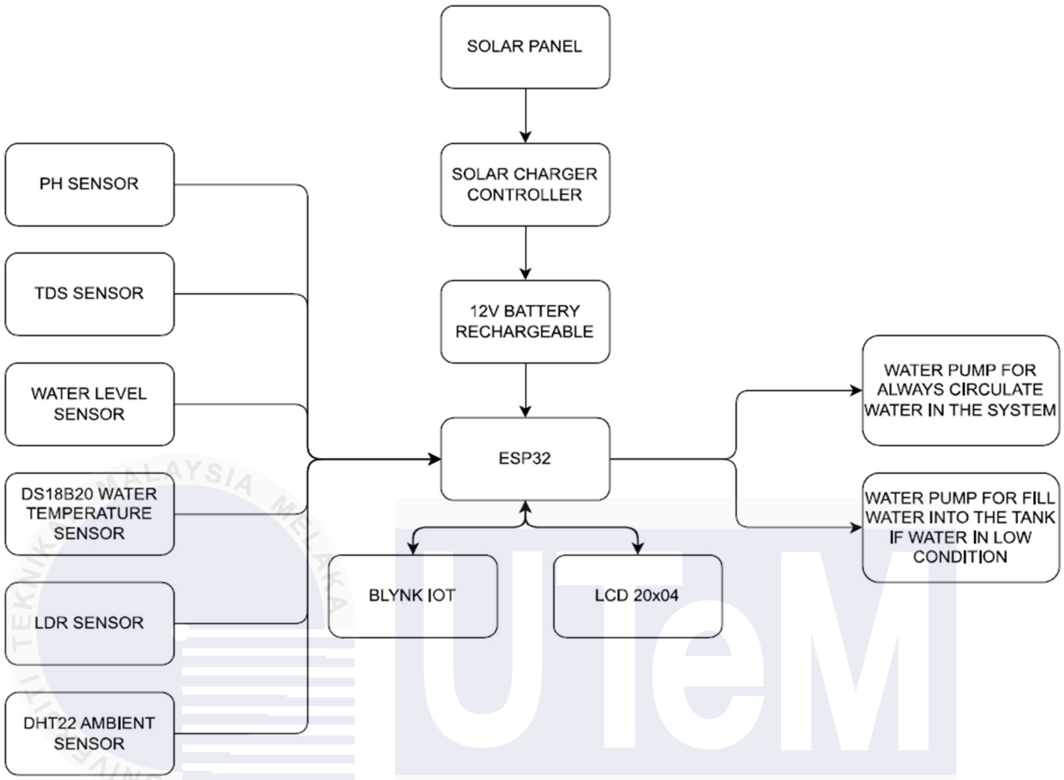

Figure 3.1 Block Diagram Hydroponic System

3.1.2 Flowchart Hydroponic System

This flowchart outlines the operation of a solar-powered hydroponic system controlled using the Blynk app. The process begins with the initialization of the database and establishing a connection with the device. A token is retrieved from the user's Blynk account to authenticate the system. Once initialized, the system checks if the device is connected. If not, it loops until a successful connection is established. Upon connection, the user can control the system (turn it on or off) via the Blynk app. When turned on, the system reads data from various sensors, including pH, TDS (Total Dissolved Solids), water level, light intensity (LDR), and temperature and humidity sensors (DS18B20 and DHT22). This sensor data is displayed in the Blynk app and on an LCD for real-time monitoring.

The system manages two water pump operations: a continuous circulation pump to ensure water movement within the hydroponic setup and an extra tank pump that activates automatically when the water level is low and stops when the water level is high. If the system is off, no pumping occurs. If it is on, the pumps operate based on the water level conditions. This setup ensures efficient and automated control of the hydroponic system while allowing users to monitor and manage it remotely through the Blynk app.

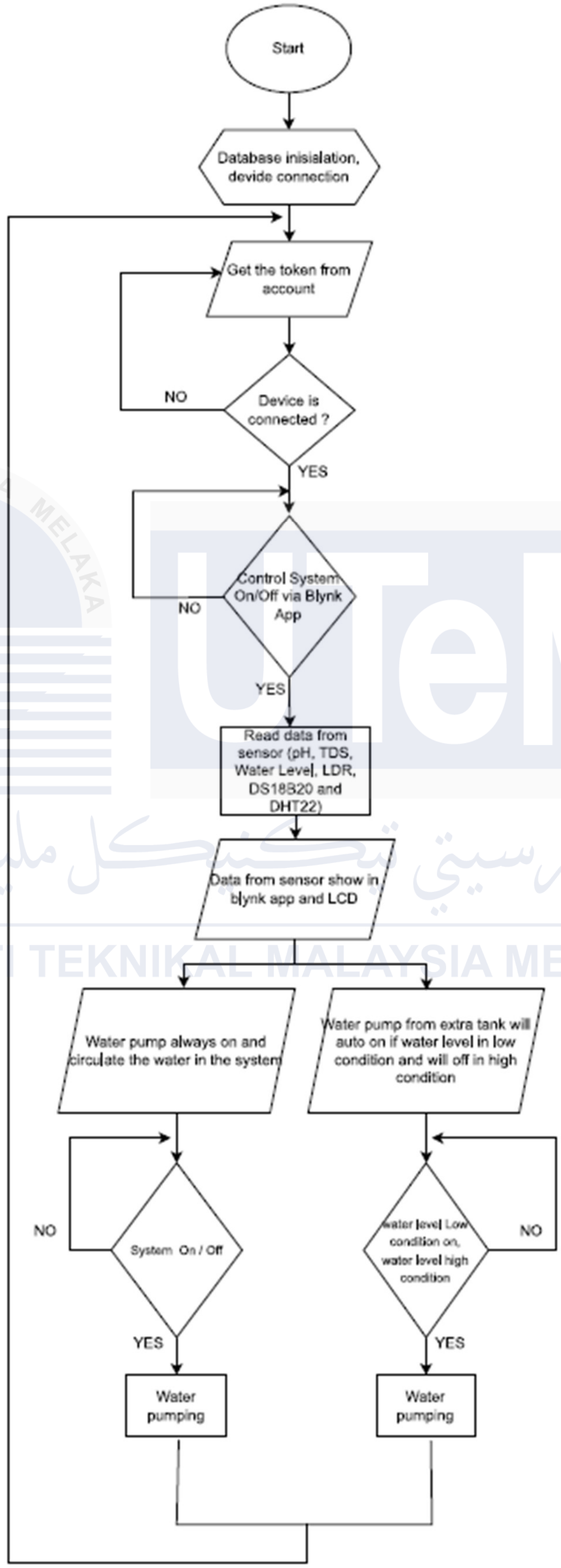

Figure 3.2 Flowchart of Control and Monitoring System

3.1.3 Circuit Design Hydroponic System

This circuit design depicts a solar-powered hydroponic system managed by an ESP32 microcontroller, integrating sensors, a display, and water pumps. At the core of the system is the ESP32 microcontroller, which facilitates sensor data collection, decision-making, and communication with the Blynk app. The ESP32 connects to various sensors, including a DS18B20 temperature sensor, a DHT22 ambient sensor, an analog pH sensor, a TDS (Total Dissolved Solids) meter, and a water level sensor, providing real-time environmental monitoring for the hydroponic setup.

The solar energy system consists of solar panels that supply power to a solar charge controller. This controller regulates energy storage in a battery and delivers power to the system's components. The charge controller ensures efficient power management, making the system eco-friendly and self-sustaining.

Water circulation is managed by two pumps. The first pump ensures continuous water flow in the hydroponic setup, while the second pump draws water from an auxiliary tank when the water level is low, as detected by the water level sensor. Both pumps are controlled via a two-channel relay module, which is interfaced with the ESP32 to automate pump operation based on sensor inputs.

The LCD2004-I2C display module is used to show real-time sensor data locally, while the Blynk app provides remote monitoring and control. A buck converter regulates the voltage supply for the water pumps, ensuring their safe operation. This integrated system leverages renewable solar energy and IoT technology to automate and optimize the hydroponic process.

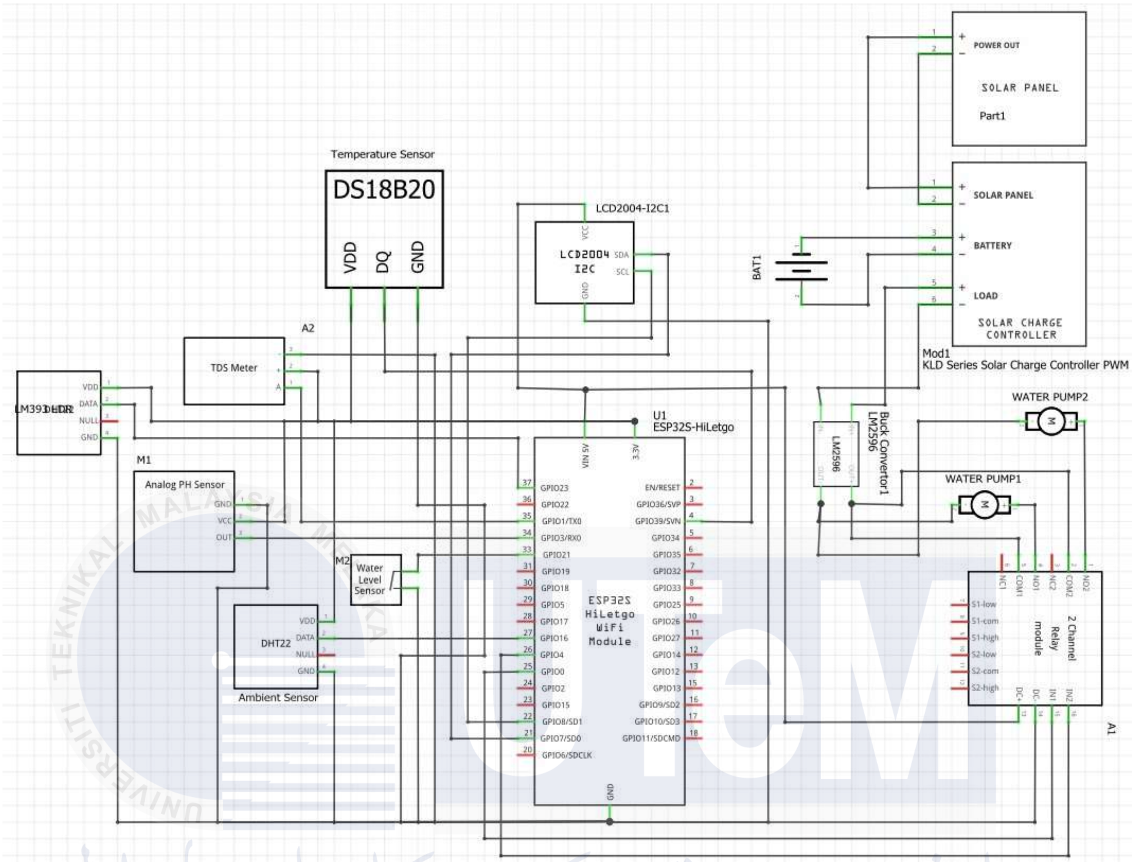

Figure 3.3 Circuit Design Hydroponic System

3.1.4 3D Cad Design

A 3D CAD design for a hydroponic system using the NFT (Nutrient Film Technique) method and powered by solar panels focuses on creating a detailed visualization of the system's components and layout. The design includes NFT channels, which are slightly inclined pipes or troughs that allow a thin film of nutrient-rich water to flow over the roots of plants held in net pots. These channels are supported by a sturdy frame, ensuring the correct slope for nutrient circulation. A reservoir tank stores the nutrient solution and is connected to the NFT channels via pipes and a water pump. The pump circulates the solution through the system in a closed loop, and the design includes connectors, elbows, and end caps to ensure seamless plumbing.

Solar panels are integrated into the design to provide renewable energy to power the water pump and other components. The panels are mounted at an optimal tilt angle for maximum sunlight exposure, and a battery system is included to store excess energy for use during low-light conditions. A solar charge controller manages the power flow between the panels, battery, and components. The wiring for the solar system and other electronic components, such as sensors, is neatly routed and incorporated into the CAD model.

This 3D CAD design provides a complete visualization of the hydroponic system, including top, side, front and 3D views to detail the arrangement, connections, and assembly process. It ensures that the system is efficient, sustainable, and ready for implementation, leveraging solar power and IoT technology to optimize hydroponic farming.

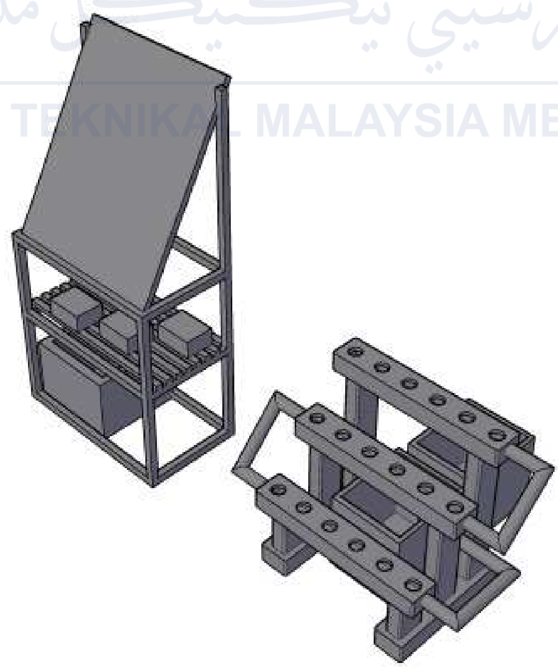

Figure 3.4 3D View

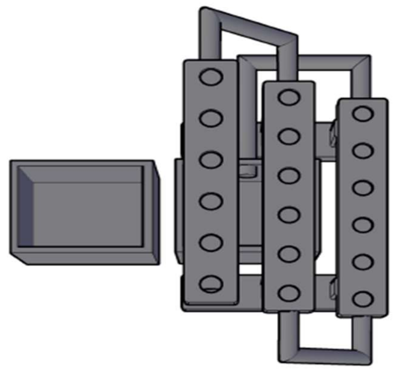

Figure 3.5 Top View

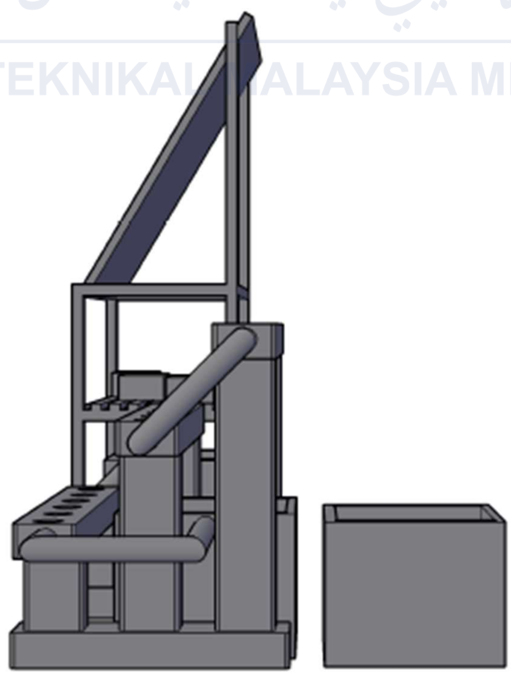

Figure 3.6 Side View

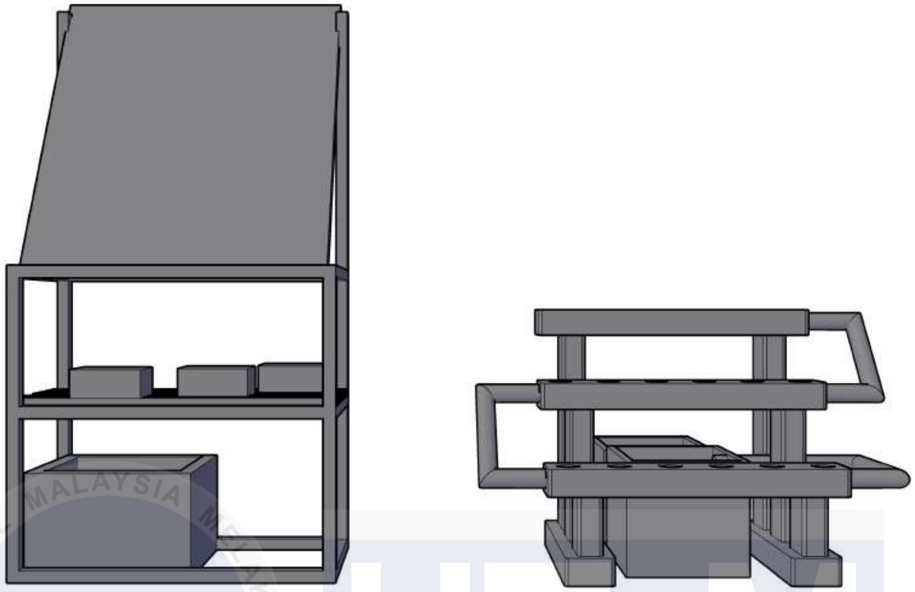

Figure 3.7 Front View

3.1.5 Coding Explanation

This hydroponic system coding integrates multiple libraries and commands to manage hardware components and communicate with the Blynk app for remote monitoring and control. The libraries used include WiFi.h for enabling WiFi connectivity, BlynkSimpleEsp32.h for connecting the ESP32 to the Blynk platform, OneWire.h and DallasTemperature.h for reading data from the DS18B20 temperature sensor, DHT.h for interfacing with the DHT22 humidity and temperature sensor, and LiquidCrystal_I2C.h for managing the LCD display.

Each sensor is connected to a specific pin on the ESP32, and its data is processed through dedicated commands. For instance, the pH sensor calculates pH levels using voltage readings, while the TDS sensor determines dissolved solids concentration. The water level sensor measures water height as a percentage, and the LDR sensor evaluates light conditions. Temperature is read using the DS18B20 sensor, and the DHT22 provides humidity readings, with calibration offsets applied to ensure accuracy.

Data from these sensors is sent to the Blynk app via Blynk.virtualWrite commands. Each virtual pin represents a specific parameter, such as pH, TDS, water level status, or temperature. Additionally, the system's state (on/off) is controlled remotely using a button in the app linked to virtual pin V3. Automation is implemented through the manageSystem() function, which continuously monitors sensor values and adjusts operations, such as activating pumps, based on predefined thresholds. Next, sensor readings and system status are displayed locally on the LCD. Furthermore, we can refer to coding in appendix C.

Overall, this program seamlessly integrates sensor monitoring, data transmission, and local and remote control, making it an efficient solution for hydroponic system management.

3.1.6 Process Explanation

The project "Solar-Powered Hydroponic System Using Blynk App" is designed to monitor and control a hydroponic system using solar energy and the Blynk application. The solar panels will generate electricity from sunlight, which is stored in the batteries and provide a reliable power source for the hydroponic system to operated. The hydroponic system uses the stored power to operate microcontrollers liked esp32, ph sensor, tds sensor, water level sensor, water temperature, humidity sensor, ldr sensor, LCD and water pump.

By using blynk app user can monitor water level in the tank, temperature water in the tank, indicating its acidity or alkalinity and concentration of dissolved solids in water, which includes salts, minerals, and other organic and inorganic substances. However, we also can control the system to on or off circulate the water in hydroponic system and automatic fill the water into the tank if water in low condition by using Blynk app. Not forget we also use LCD20x04 to monitor its system on/off, pH sensor, TDS sensor, water temperature sensor, water level sensor, humidity sensor, and ldr sensor. The system uses Wi-Fi connectivity to transmit data from the sensors to the Blynk app, allowing users to access real-time information about the plants.

Lastly the method that use for this hydroponic system project is nutrient film technique (NFT). The Nutrient Film Technique (NFT) is a popular hydroponic system where a thin film of nutrient-rich water continuously flows over the roots of plants. This method involves placing plants in sloping channels, with the nutrient solution pumped from a reservoir to the higher end of the channel. As the solution flows down, it provides the plants with necessary nutrients before being collected back into the reservoir to be recirculated. This technique ensures that the roots get ample oxygen while absorbing nutrients, leading to efficient growth and high yields. NFT systems are particularly well-suited for growing leafy greens and herbs.

3.2 Components and Software Review of The Hydroponic System

3.2.1 Review on Selected Components

3.2.1.1 ESP32-Wroom

The ESP32-WROOM is a powerful, generic Wi-Fi + Bluetooth + Bluetooth LE MCU module designed by Espressif Systems. It features two low-power Xtensa 32-bit LX6 microprocessors, 448 KBytes of ROM for booting and core functions, and 520 KBytes of on-chip SRAM. The module supports Wi-Fi protocols up to 802.11n at 150 Mbps and Bluetooth v4.2 BR/EDR and BLE specification. It has a wide range of interfaces including SD card, UART, SPI, SDIO, I2C, LED PWM, Motor PWM, I2S, IR, GPIO, capacitive touch sensor, ADC, DAC, and on-chip sensors for Hall and temperature. The module operates at a voltage range of 2.2-3.6V and has a typical consumption of 80 mA. It supports secure OTA firmware upgrades and is suitable for a variety of applications, from low-power sensor networks to demanding tasks such as voice encoding and music streaming.

Figure 3.8 ESP32-WROOM

3.2.1.2 ESP32 Extension Board

An ESP32 extension board is an accessory that enhances the functionality of the ESP32 microcontroller, making it easier to connect peripherals and build projects. It provides labeled GPIO pins for simple wiring, power management options, and a USB interface for programming and debugging. Some extension boards include extra features like relays, SD card slots, or onboard displays, catering to specific needs. Essentially, it simplifies prototyping and development by offering a convenient platform to connect sensors, actuators, and other components to the ESP32.

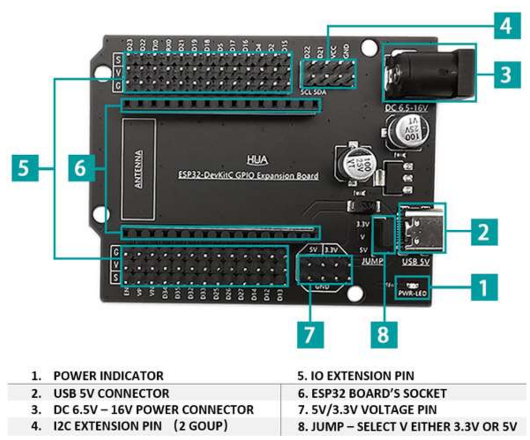

Figure 3.9 Extension Board

3.2.1.3 Total Dissolved Solids (TDS) Sensor

A TDS sensor used in hydroponic systems is a device specifically designed to measure the total dissolved solids in the nutrient solution, providing a quick and accurate reading of the TDS level. These sensors are crucial for maintaining optimal nutrient levels in hydroponics, allowing growers to monitor and fine-tune the nutrient concentration to prevent imbalances and maximize plant growth. The ideal TDS range varies depending on the plant species, growth stage, and nutrient solution formulation, typically falling between 800 and 1500 parts per million (ppm) for most hydroponic crops. By utilizing a quality TDS meter and adhering to crop-specific guidelines, hydroponic gardeners can create an ideal nutrient environment that supports vibrant growth in their systems.

The specification for a TDS sensor typically includes the following parameters: input voltage (3.3-5.5V), output voltage (0-2.3V), working current (3-6mA), TDS measurement range (0-1000 ppm), and TDS measurement accuracy (± 10% FS at 25°C). The sensor is designed to be waterproof and can be immersed in water for long-term measurement. It uses an AC signal excitation source to prevent polarization and prolong the life of the probe, ensuring a stable output signal. The TDS sensor is compatible with both 5V and 3.3V control systems or boards, making it versatile for various applications.

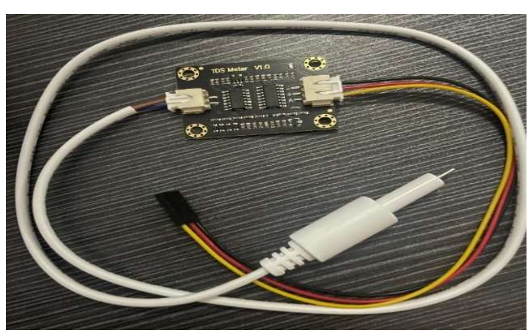

Figure 3.10 Total Dissolved Solids (TDS) Sensor

3.2.1.4 Ph Sensor

A pH sensor designed for hydroponic systems is a crucial component for monitoring and controlling the acidity or alkalinity of the nutrient solution. Typically, these sensors have a measurement range suitable for hydroponic applications, such as 0 to 14 pH, with an accuracy of around ±0.1 pH. They are often equipped with features like waterproofing to withstand the hydroponic environment and compatibility with microcontrollers like the ESP32 for data processing and automation. These sensors play a vital role in ensuring optimal nutrient uptake by plants, with some models capable of alerting growers when pH levels deviate from the ideal range of 5.5 to 7.0, allowing for timely adjustments to maintain plant health and maximize growth in hydroponic setups.

Figure 3.11 Ph Sensor

3.2.1.5 Water Level Sensor

A water level sensor is a device used to detect the presence or absence of water at a specific level. It typically consists of a series of parallel exposed copper traces, with some acting as power traces and others as sense traces. When immersed in water, these traces are bridged, allowing the sensor to measure the water level. The sensor generates an output voltage proportional to the resistance, which varies based on the water level. Key specifications include an operating voltage of DC 3-5V, operating current less than 20mA, analog sensor type, and operating temperature range of 10°C-30°C. These sensors are compact, lightweight, and cost-effective, making them suitable for applications such as water level alarms, stream-level indicators, and pump control systems.

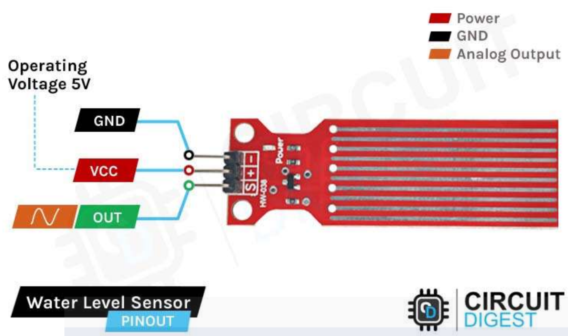

Figure 3.12 Water Level Sensor

3.2.1.6 DS18B20 Temperature Sensor

The DS18B20 is a digital temperature sensor that measures temperatures accurately in the range of -55°C to +125°C. It communicates using a simple 1-Wire interface, which means it requires only one data line (plus ground) to connect to a microcontroller. The sensor provides precise readings in increments of 0.1°C and has a built-in unique 64-bit serial code, allowing multiple sensors to be connected on the same wire. It is compact, reliable, and commonly used in IoT, weather monitoring, and industrial applications.

Figure 3.13 Temperature Sensor

3.2.1.7 DHT22 Humidity Sensor

The DHT22 is a digital sensor used to measure both temperature and humidity with high accuracy. It provides temperature readings from -40°C to +80°C and humidity readings from 0% to 100% with good precision. The sensor communicates with a microcontroller using a single digital pin, making it simple to use. It is reliable, affordable, and commonly used in applications like weather monitoring, indoor climate control, and IoT projects. The DHT22 is slightly larger and more accurate than its counterpart, the DHT11.

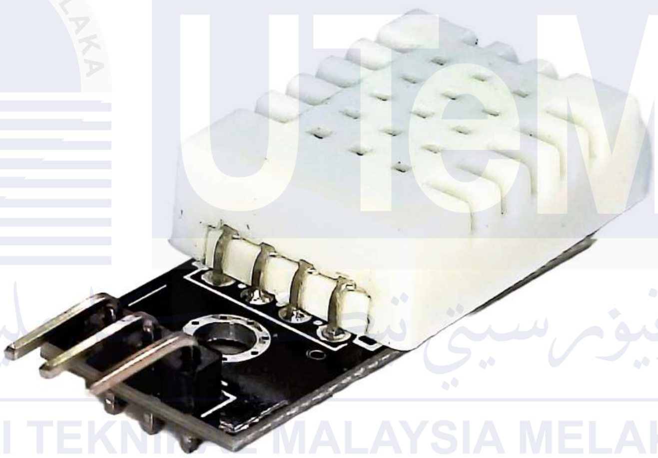

Figure 3.14 Humidity Sensor

3.2.1.8 LDR Sensor

An LDR (Light Dependent Resistor) sensor, also known as a photoresistor, is a device that detects light intensity. Its resistance decreases when exposed to bright light and increases in the dark, making it ideal for measuring light levels. It is simple to use and commonly found in applications like automatic streetlights, light meters, and brightness control systems. The LDR is cost-effective and widely used for light-sensing tasks in electronics projects.

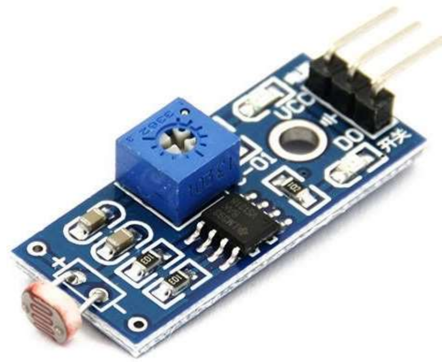

Figure 3.15 LDR Sensor

3.2.1.5 2 Channel Relay 12V Module

The 2 Channel 12V Relay Module with Optocoupler is a versatile and robust component designed for secure device control. It features two independent channels, each capable of controlling devices with high currents up to 10A at 250VAC and 10A at 30VDC. The module operates at 12V DC and includes optocoupler technology for electrical isolation between the input and output, protecting microcontrollers and other sensitive components. It has high-quality screw terminals for easy connection and includes a freewheeling diode to protect the microcontroller. The module also features LED status indicators and mounting holes for convenient integration. It is suitable for various applications, including home automation, robotics, industrial control, and IoT projects.

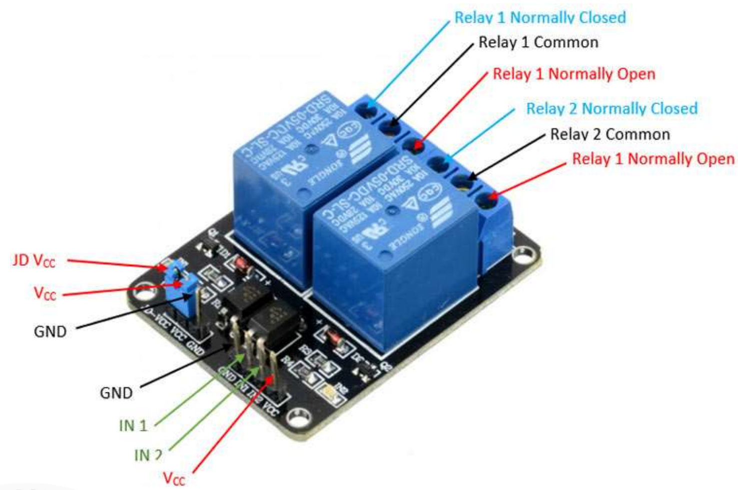

Figure 3.16 2 Channel Relay 12V Module

3.2.1.6 Buck Converter Module

A buck converter, or step-down converter, is a DC-DC converter that reduces a higher input voltage to a lower output voltage using a combination of key components such as a high-side switch (typically a MOSFET), a low-side switch (either a diode or another MOSFET in synchronous designs), an inductor, and an output capacitor. The high-side switch is controlled by a Pulse Width Modulation (PWM) signal to regulate the duty cycle, which in turn controls the average output voltage. The inductor stores energy when the switch is on and releases it when the switch is off, smoothing the current flow. The output capacitor filters the voltage to reduce ripple and provide a stable output. Buck converters are highly efficient and are used in various applications, including battery charging, portable devices, and automotive systems, with specifications such as input voltage range (e.g., 14V to 40V), output voltage (e.g., 12V), output current (e.g., up to 1.5A), and efficiency (up to 93%).

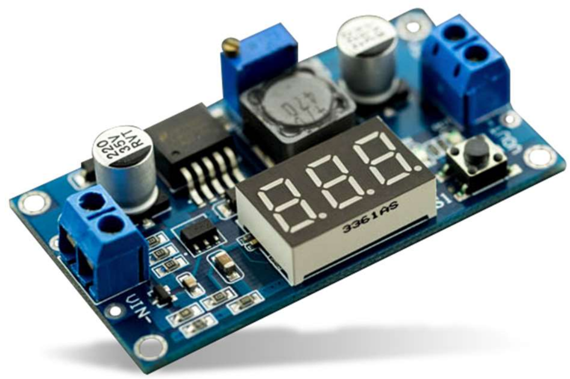

Figure 3.17 Buck Converter Module

3.2.1.7 DC 12V Submersible Water Pump AD20P

The AD20P is a small, efficient water pump designed for various applications like water circulation, aquariums, or cooling systems. It operates on a 12V DC power supply, consuming 300mA of current, which makes it energy efficient. The pump has a flow rate of 240 liters per hour (L/h), providing a steady and reliable water flow. Compact and lightweight, it is easy to use in low-pressure systems and is ideal for small-scale water pumping tasks.

Figure 3.18 Submersible Water Pump

3.2.1.8 R385 DC 12V Pneumatic Diaphragm Water Pump

The R385 is a versatile water pump designed for applications like liquid transfer, cooling, and small-scale irrigation. It operates on a 12V DC power supply, making it compatible with batteries or power adapters. Known for its durability and efficiency, the pump can handle various liquids, including water and light chemicals. It has a good flow rate and pressure, suitable for tasks like aquariums, fountains, and DIY projects. Its compact design makes it easy to integrate into systems, and it is widely used in hobbyist and industrial applications.

Figure 3.19 Pneumatic Diaphragm Water Pump

3.2.1.9 100W 12V/24V Polycrystalline Solar Panel

A 100W polycrystalline solar panel is a renewable energy device made from multiple silicon crystals, offering good efficiency and affordability. It generates up to 100 watts of power with a ±5% tolerance under optimal sunlight conditions. The panel has a maximum power voltage (Vmp) of 18.5V and a maximum power current (Imp) of 5.4A. Its open-circuit voltage (Voc) is 22.1V, and the short-circuit current (Isc) is 6A. With dimensions of 770mm x 670mm x 30mm and a weight of 6kg, it is compact and easy to install on rooftops, boats, or

RVs. This panel is commonly used for off-grid solar systems, portable power setups, and small-scale energy needs, providing a reliable and efficient energy source.

Figure 3.20 100W 12/24V Polycrystalline Solar Panel

3.2.1.10 Solar Charger Controller

Solar charge controllers are devices that regulate the voltage and current from solar panels to prevent overcharging and damaging the battery. They are rated by voltage (12V, 24V, 48V) and current (1A to 100A), with higher voltage and current models being more expensive. Simple PWM controllers are the cheapest, while advanced MPPT controllers can convert the high voltage from solar panels to the lower voltage needed for battery charging, allowing for longer wire runs and higher efficiency. Key specifications to consider are rated current, rated voltage, and features like displays, datalogging, and reverse current protection.

Figure 3.21 Solar Charger Controller

3.2.1.11 12V Lead Acid Rechargeable Battery

Rechargeable 12V lead acid batteries are a type of battery commonly used in various applications such as vehicles, backup power systems, and portable electrical equipment. These batteries have a nominal voltage of 12V and varying capacities, for example, 7Ah, 7.2Ah, and 40Ah. These batteries typically use lead plate technology and sulfuric acid electrolytes, which allow energy storage through reversible chemical reactions. 12V lead acid batteries are durable, low cost, and require minimal maintenance. However, it has low energy efficiency and higher weight compared to other modern batteries. Additional specifications include physical size, weight, and features such as maintenance-free and high vibration resistance, suitable for use in extreme conditions.

Figure 3.22 12V Lead Acid Rechargeable Battery

3.2.1.12 LCD 20x04

The LCD 20x4 is a display module with 20 columns and 4 rows, capable of showing up to 80 characters at a time. It uses liquid crystal technology to display text or simple symbols, making it ideal for projects where information like sensor readings or system status needs to be shown. The display works with a microcontroller, such as an Arduino or ESP32, through parallel data communication or I2C for fewer connections. It's energy-efficient and easy to use, often featuring a backlight for visibility in low-light conditions.

Figure 3.23 LCD 20x04

3.2.2 Review on Selected Software

3.2.2.1 Blynk Software

Blynk is a versatile IoT platform that simplifies the connection of devices to the cloud, enabling users to build mobile apps for remote monitoring and control, manage thousands of users and products, and facilitate the transition from prototype to commercial deployment. With features like device provisioning, management, data storage, alerts, notifications, and user management, Blynk caters to both businesses and individuals looking to create and manage connected products seamlessly.

The platform is hardware-agnostic, supporting a wide range of devices, and offers a suite of software products for monitoring and controlling connected devices, making it a comprehensive solution for IoT projects of varying scales and complexities.

Figure 3.24 Blynk App

3.2.2.2 Arduino IDE

The Arduino Integrated Development Environment (IDE) is an open-source software used to write, compile, and upload code to microcontroller boards. It supports multiple operating systems and programming languages like C/C++.

The IDE provides a text editor, compiler, and tools for debugging and uploading code to the board. It has a user-friendly interface with a toolbar containing buttons for common functions like verifying, uploading, creating, opening, and saving sketches (code files). The Arduino IDE simplifies the process of programming microcontrollers, making it accessible to beginners and hobbyists looking to create interactive projects and prototypes.

Figure 3.25 Arduino IDE

3.2.2.3 Fritzing Software

Fritzing is an open-source electronics design automation (EDA) software tool intended to allow designers and artists to build more permanent circuits from prototypes. It was developed at the University of Applied Sciences Potsdam and is free software under the GPL 3.0 or later license. Fritzing allows users to document their Arduino-based prototype, create a PCB layout for manufacturing, and order PCBs through the FritzingFab service.

The software is written in C++ using the Qt framework and runs on Windows, macOS, and Linux. Fritzing aims to make creative use of electronics accessible to everyone by providing a software tool, community website, and services in the spirit of Processing and Arduino.

Figure 3.26 Fritzing Software

3.2.2.4 AutoCAD 2025

AutoCAD is a widely used software developed by Autodesk for creating detailed 2D and 3D designs. It is mainly used by professionals in fields like architecture, engineering, and product design to create accurate drawings and models. With AutoCAD, users can design everything from floor plans to mechanical parts and electrical systems. The software includes tools for precision drafting, 3D modeling, and annotation, allowing users to add text, labels, and measurements to their drawings. It also offers features like reusable design blocks, layer management, and file formats like DWG and DXF for easy sharing and collaboration.

AutoCAD comes in different versions for specific industries, such as AutoCAD Architecture or AutoCAD Mechanical. In addition, AutoCAD can be used to design specialized systems like hydroponic systems and solar panel layouts. While it can be complex for beginners, it provides powerful features for professionals and is available through subscription-based licenses.

Figure 3.27 AutoCAD 2025 Software

3.4 Summary

This chapter outlines the design and implementation process for a solar-powered hydroponic system using the Nutrient Film Technique (NFT) method, integrated with IoT technology via the Blynk app. The system's components include an ESP32 microcontroller, sensors for monitoring pH, TDS, water temperature, and water level, a solar panel, and a battery for sustainable power supply. A block diagram and flowchart illustrate the system's operation, where data from sensors is processed by the ESP32 and transmitted to the Blynk app for real-time monitoring and control. The hydroponic setup ensures water and nutrient circulation through pumps, with automation for refilling water when low levels are detected. The methodology emphasizes the integration of renewable energy, efficient water use, and smart control to optimize plant growth in a controlled environment.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

Preliminary findings from the investigation and experiment have offered insightful information early on. It's crucial to remember that these findings could alter or be revised in the future as new information is gathered and examined. These initial results provide the groundwork for additional research and improvement. As for expected findings, they are projected outcomes that originate from prior studies and current understanding. Based on their theories, researchers expect these projected results to materialize. It's important to remember, though, that the final outcomes might not match your early projections. Understanding the relevance of the data and deciding whether they match the anticipated outcomes were made possible by them. analytical process. Researchers were able to find patterns, make comparisons, and eventually come to conclusions by carefully examining and interpreting the data or results. A greater comprehension of the study results and their ramifications is offered by this thorough examination.

4.1.1 Development of Solar-Powered Hydroponic System Using Blynk App

Figure 4.1 Solar-Powered Hydroponic System

According to the literature review, the hydroponic system's configuration has been chosen to make it simple to operate, maintain, and improve. The advantage provided by the hydroponic system compared to conventional cultivation is that the water used in the hydroponic system can be recycled and carefully controlled to provide optimal nutrition for plants. In this approach, lettuce plant are used as an agriculture plant starting with the method hydroponic system.

Figure 4.2 Nutrient Film Technique (NFT)

Based on figure 3.30 the development of the hydroponic system using the Nutrient Film Technique (NFT) method involves creating an efficient structure for growing plants, where a thin film of nutrient-rich water continuously flows over the roots. The system is built with horizontal PVC channels arranged in tiers, each having evenly spaced holes to hold net pots for the plants. The roots of the plants dangle inside the channels, allowing them to absorb nutrients from the flowing water while being exposed to air for oxygen uptake. At the base of the system is a reservoir tank that stores the nutrient solution and houses a submersible water pump responsible for circulating the solution throughout the system.

Figure 4.3 Submersible Water Pump

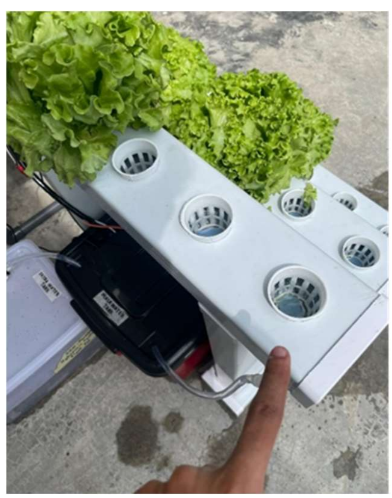

Figure 4.4 Inlet Nutrient Film Technique (NFT)

The water circulation process begins with the figure 3.31 submersible water pump drawing nutrient solution from the reservoir which is main water tank that is placed inside the hydroponic system and pushing it through pipes to the inlet of top NFT channel, is shown in figure 3.32. These channels are inclined to facilitate the smooth flow of the solution along their length, forming a thin film that ensures the plant roots are consistently wet without being submerged.

Figure 4.5 Outlet Nutrient Film Technique (NFT)

After traveling through the channels, figure 3.33 shows the water exits via the **outlet** and is collected into return pipes that funnel it back into the reservoir, completing the circulation loop.

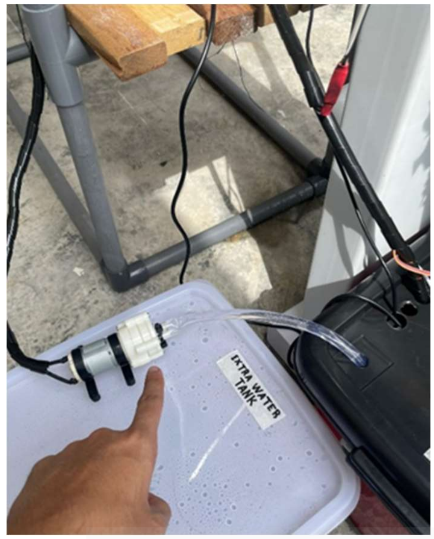

Figure 4.6 Extra Water Tank and Pneumatic Diaphragm Water Pump

As shown figure 3.34, we also have an extra water tank that is placed next to the hydroponic system where the function is when the water level sensor detects water in a Low condition, the pneumatic diaphragm water pump will add water from the extra water tank to the main water tank until it is in a high condition.

This continuous flow ensures the plants receive a constant supply of nutrients, water, and oxygen, essential for optimal growth. The nutrient solution is periodically monitored and replenished in the reservoir to maintain the correct concentration. The system's efficiency lies in its minimal water usage due to the re-circulation process, making it sustainable and resource friendly. This NFT system is ideal for growing leafy greens, herbs, and other fast-growing plants in a controlled and sustainable manner.

Figure 4.7 LDR Sensor Placement

Figure 4.8 Humidiy Sensor Placement

As shown in figure 3.35, the location of the LDR sensor is at the top of the hydroponic system because of its function to detect weather conditions such as dark, cloudy and sunny. Next is humidity sensor which is placed between lettuce plant to monitor humidity in percentage, is shown in figure 3.36.

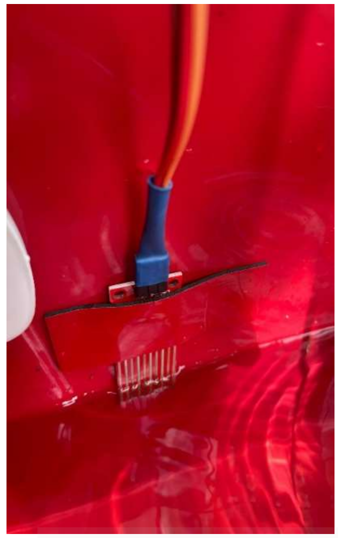

Figure 4.9 Water Level Sensor Placement

Next is the water level sensor, which is placed inside the main water tank to detect the height of the water level, shown in figure 3.37.

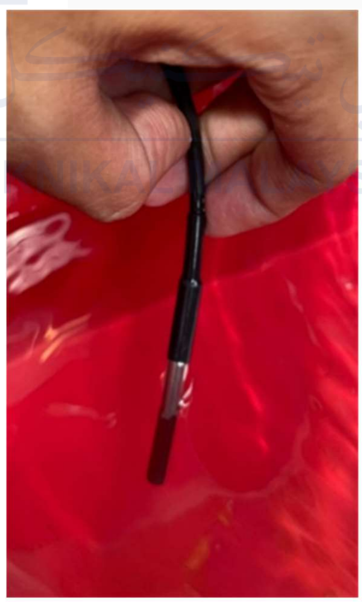

Figure 4.10 Temperature Sensor Placement

As we can see, figure 3.38 shows the temperature sensor placed inside the main water tank to monitor water temperature conditions.

Figure 4.11 PH Sensor Placement

Figure 4.12 TDS Sensor Placement

Figure 3.39 and figure 3.40 also placed inside main water tank which is function figure 3.39 pH sensor is to monitor water pH value within range 6.5 till 7.0 pH. While figure 3.40 Tds sensor is to detects the Total Dissolved Solids (TDS) levels in the water which can be used to indicate the water quality.

Figure 4.13 Solar Panel Placement

The development of the solar power system for the hydroponic setup integrates a polycrystalline solar panel, a solar charge controller, a 12V lead-acid rechargeable battery, and a load that includes a microcontroller and related components. The polycrystalline solar panel is placed next to the hydroponic system and uses a PVC frame to mount the solar panel, and installed at an optimal angle to efficiently capture sunlight and convert it into direct current (DC) electricity, shown in figure 3.41. This energy, typically ranging between 18-24V depending on sunlight intensity, is sent to a solar charge controller.

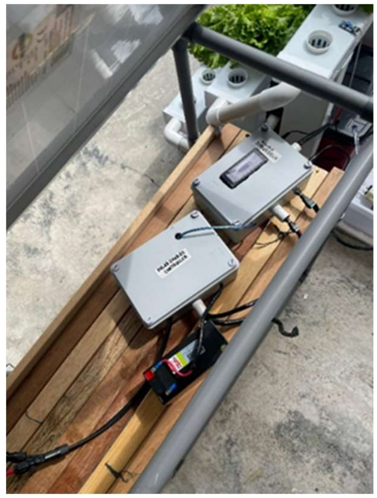

Figure 4.14 Solar Charger Controller, Control Box and Battery

The solar charger controller is placed between the battery and the control box. Function is to regulate the voltage and current to protect the battery from overcharging, over-discharging, and reverse current flow, ensuring efficient and safe energy storage, shown in figure 3.42. The regulated power from the charge controller charges the 12V lead-acid rechargeable battery, which serves as an energy reservoir. This battery stores excess power generated during the day and provides a consistent 12V DC output to keep the system running during low sunlight or nighttime.

Figure 4.15 Control Box

From the battery, power is distributed to the load, including the microcontroller (e.g., ESP32) and other components like sensors, relays, and water pumps. The microcontroller manages the hydroponic system's operations, such as monitoring sensor data, controlling water circulation, and automating processes.

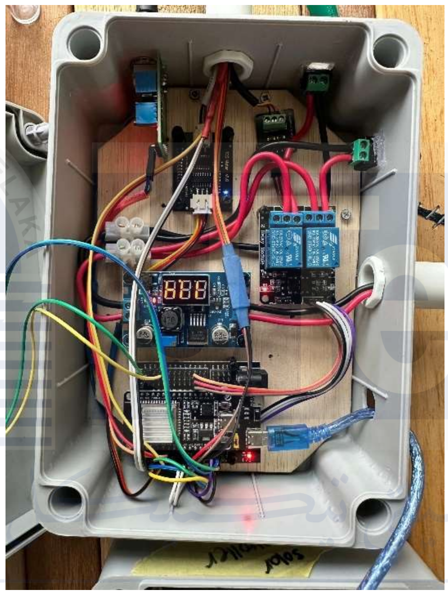

Figure 4.16 Wiring Inside Control Box

The control box serves as the central hub for managing the hydroponic system's operations, housing various components and connections necessary for automation, shown in figure 3.44. At its core is a microcontroller, such as an ESP32, which controls inputs and outputs, including sensors and relays. The microcontroller is powered via a USB connection or through a voltage regulator module, which steps down the voltage from the battery to suitable levels for all connected components. Relay modules are included to act as switches, enabling the microcontroller to control high-power devices like water pumps. Various sensors, such as TDS, pH, and temperature sensors, are wired to the microcontroller, providing real-time data to automate system adjustments. Inside the box, red and black wires distribute power, while multicolored signal wires connect the sensors and relays to the microcontroller's GPIO pins. Terminal blocks are used for neat and organized connections, ensuring efficient power distribution and easy maintenance. The control box is designed with proper insulation and grommets to protect the wires and ensure safety, providing a reliable and efficient setup for the hydroponic system.

Figure 4.17 Blynk App and LCD 20x04

The development of IoT integration for the hydroponic system uses the Blynk app and an LCD 20x04 to monitor and control system parameters. The Blynk app provides real-time data visualization and remote control via a smartphone, showing key metrics like TDS (Total Dissolved Solids), water pH, and temperature. The ESP32 microcontroller connects to Wi-Fi to transmit sensor data to the Blynk app, enabling users to adjust system settings remotely. Simultaneously, the LCD 20x04 displays real-time information directly on the control box, such as system status, sensor readings, and alerts, offering a convenient local monitoring option. This dual-display approach ensures flexibility, allowing users to manage the system both on-site and remotely for optimal performance and maintenance.

4.2 Results and Analysis

4.2.1 Water Temperature and Humidity

Table 4.1 Data Water Temperature for 7 Days (20/12/2024 - 26/12/2024)

Data Water Temperature (˚C)											
Time Day	6:00 AM	8:00 AM	10:00 AM	12:00 AM	2:00 PM	4:00 PM	6:00 PM	8:00 PM	10:00 PM	12:00 PM	2:00 AM
1	24.40	25.80	27.90	29.70	29.50	28.50	27.71	26.67	25.77	25.54	24.62
2	24.66	25.76	26.40	26.67	25.96	25.70	25.38	24.92	24.56	24.31	24.44
3	24.57	25.32	26.10	27.35	27.85	27.38	26.81	26.55	26.20	25.40	24.90
4	23.90	25.55	27.33	28.62	30.10	31.40	30.60	25.40	25.65	25.64	25.34
5	24.21	26.10	27.54	28.96	29.54	29.37	28.88	25.17	24.84	24.60	24.71
6	24.00	25.36	25.45	28.74	30.54	28.15	27.00	26.55	25.12	25.20	25.25
7	24.51	25.28	28.55	29.61	30.03	29.28	28.10	28.32	25.33	24.29	24.20
Average	24.32	25.60	27.04	28.52	29.07	28.54	27.78	26.23	25.35	25.00	24.78

The water temperature data for the hydroponic system setup highlights fluctuations over a seven-day period, measured at various times of the day. Lettuce, which thrives in water temperatures between 20°C and 25°C, experiences favourable conditions during the early morning (6:00 AM to 10:00 AM) and late evening (6:00 PM to 2:00 AM), when temperatures range from 24°C to 26°C. However, during the afternoon (12:00 PM to 4:00 PM), temperatures peak between 28°C and 31°C, which may cause heat stress and affect nutrient uptake and growth. To ensure optimal lettuce cultivation, it is essential to regulate water temperature, particularly during the hottest hours, by using methods such as shading, proper ventilation, or cooling mechanisms to maintain ideal growing conditions.

Table 4.2 Data Humidity for 7 Days (20/12/2024 - 26/12/2024)

Data Humidity (%)											
Time Day	6:00 AM	8:00 AM	10:00 AM	12:00 PM	2:00 PM	4:00 PM	6:00 PM	8:00 PM	10:00 PM	12:00 AM	2:00 AM
1	60.30	60.10	56.50	42.40	40.70	47.30	50.50	61.00	60.70	62.30	61.60
2	61.20	61.30	60.00	60.20	61.60	64.40	65.00	63.10	62.80	61.30	61.20
3	63.00	61.90	57.20	55.50	52.70	55.20	55.10	60.00	65.30	62.10	62.80
4	60.50	53.00	42.60	39.90	38.40	41.20	48.30	59.30	59.90	62.50	62.10
5	62.10	60.00	58.60	38.30	41.50	53.20	58.10	60.00	61.20	62.00	61.40
6	61.60	60.70	60.20	36.70	39.10	55.00	58.30	60.80	60.50	61.10	60.60
7	62.30	60.50	46.00	36.30	38.50	50.60	53.70	57.50	61.00	60.90	61.70
Average	61.57	59.64	54.44	44.19	44.64	52.41	55.57	60.24	61.63	61.74	61.63

The data shows the humidity levels recorded at different times of the day over seven days for a hydroponic system, which is critical for lettuce cultivation. Humidity generally peaks in the early morning (around 6:00 AM) and at night (after 8:00 PM), ranging from 60% to 63%. During midday and early afternoon (10:00 AM to 4:00 PM), humidity levels significantly drop, often reaching their lowest values, especially on days 4, 5, 6, and 7, where it falls to as low as 36%–42%. This variation is due to increased temperatures during peak sunlight hours, leading to higher evaporation rates.

Maintaining optimal humidity is essential for lettuce growth, as low humidity can cause water stress and hinder plant development. To address this, measures such as misting systems, shading to reduce heat, or enclosing the hydroponic setup with controlled ventilation can help stabilize humidity levels during the hotter parts of the day. Such interventions can ensure consistent and favorable growing conditions for lettuce throughout the day.

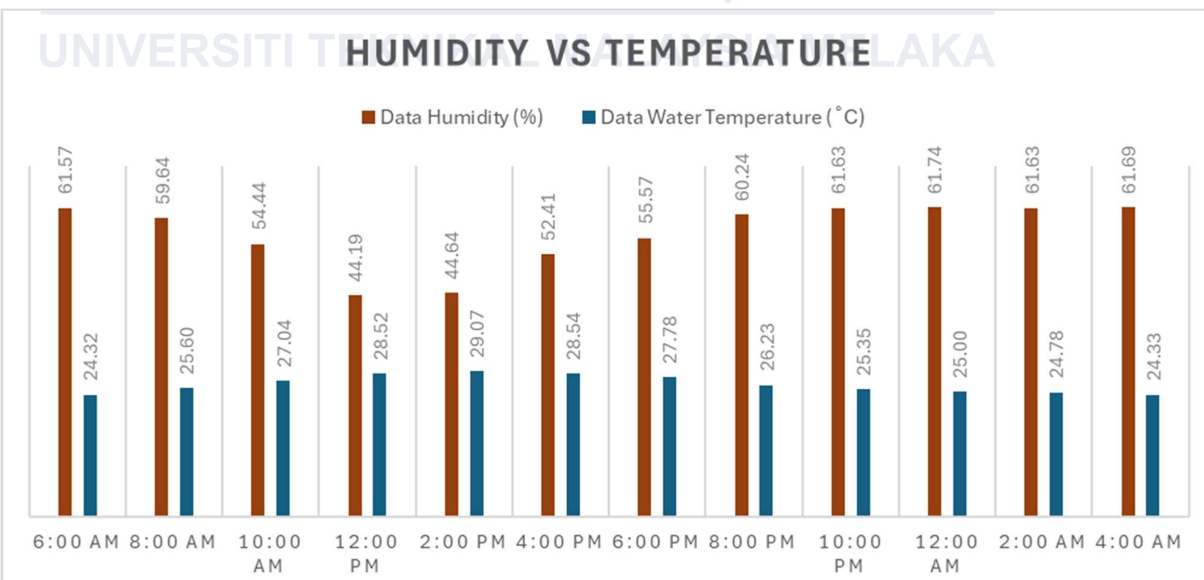

Figure 4.18 Graph Humidity and Temperature

4.2.2 Lettuce Leaf Growth Rate

Table 4.3 Lettuce Leaf Growth Rate for 4 Weeks

Lettuce Leaf Size Radius (cm)				
Week Test	1	2	3	4
1	12.35	13.98	16.60	18.20
2	12.40	14.03	16.80	18.30
3	12.38	14.10	16.80	18.20
Average	12.38	14.04	16.73	18.23

The data tracks the growth of lettuce leaf size, measured by radius in centimeters, across four weeks based on three separate tests. In the first test, the leaf size starts at 12.35 cm in Week 1 and grows to 18.20 cm by Week 4. The second test follows a similar pattern, starting at 12.40 cm and ending at 18.30 cm, while the third test starts at 12.38 cm and ends at 18.20 cm. The average values for each week are calculated by taking the mean of the three tests: 12.38 cm in Week 1, 14.04 cm in Week 2, 16.73 cm in Week 3, and 18.23 cm in Week 4. Overall, the leaf size shows steady growth, with the most rapid increase occurring between Weeks 1 and 2, followed by a slower, more consistent growth rate in the subsequent weeks. The data indicates that the lettuce leaf grows approximately 1.66 cm per week in the initial phase, with the growth rate slowing to about 0.20 cm per week in the later phase.

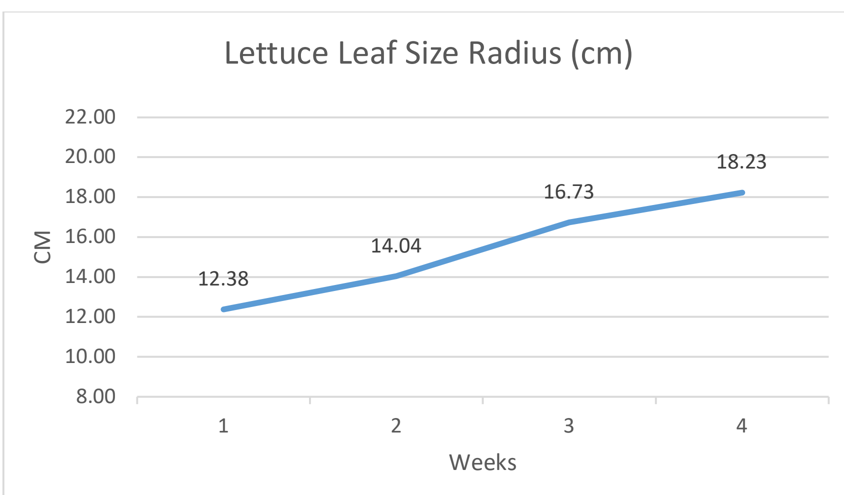

Figure 4.19 Lettuce Leaf Growth Rate

4.2.3 PH, Total Dissolved Solids and Water Level

Table 4.4 Data pH for 7 Days (20/12/2024 - 26/12/2024)

Data pH (pH)												
Time Day	6:00 AM	8:00 AM	10:00 AM	12:00 AM	2:00 PM	4:00 PM	6:00 PM	8:00 PM	10:00 PM	12:00 AM	2:00 AM	Average
1	6.50	6.51	6.50	6.50	6.49	6.50	6.48	6.49	6.47	6.51	6.48	6.49
2	6.47	6.50	6.52	6.48	6.54	6.50	6.44	6.61	6.55	6.40	6.78	6.53
3	6.55	6.54	6.44	6.52	6.58	6.56	6.50	6.46	6.40	6.33	6.52	6.49
4	6.50	6.52	6.47	6.44	6.50	6.58	6.60	6.32	6.45	6.57	6.48	6.49
5	6.51	6.64	6.48	6.48	6.50	6.45	6.49	6.52	6.42	6.22	6.46	6.47
6	6.46	6.35	6.28	6.44	6.21	6.55	6.54	6.66	6.80	6.32	6.45	6.46
7	8.24	8.20	8.22	8.25	6.43	6.64	6.44	6.50	6.33	6.48	6.52	7.11

The data from the table shows the pH levels of a hydroponic system over seven days, with readings taken at multiple times throughout each day. The pH levels are crucial for the health of lettuce plants in hydroponics, as they prefer a slightly acidic to neutral range (5.5 to 6.5). From Day 1 to Day 4, the pH levels remain relatively stable, mostly fluctuating between 6.44 and 6.64, which is within the ideal range for lettuce. However, on Day 5, while the pH stays within the acceptable range, there are some minor fluctuations. Day 6 shows more significant variation, with the pH dropping as low as 6.21 and rising to 6.80. Such fluctuations may indicate issues such as nutrient imbalances or environmental changes, which could impact plant health. The most concerning data appears on Day 7, where the pH starts at 8.24, far beyond the optimal range, and though it drops later in the day, the fluctuations are still too high. This could cause nutrient lockout, where the plants cannot properly absorb essential nutrients. In summary, while the system performs well for most of the week, Day 7 presents a critical issue that needs immediate attention to prevent damage to the lettuce plants. Addressing the cause of these pH spikes and ensuring more consistent readings is essential for maintaining healthy plant growth.

Table 4.5 Data Total Dissolved Solids (TDS) for 7 Days (20/12/2024 - 26/12/2024)

Data TDS (ppm)												
Time Day	6:00 AM	8:00 AM	10:00 AM	12:00 AM	2:00 PM	4:00 PM	6:00 PM	8:00 PM	10:00 PM	12:00 PM	2:00 AM	Average
1	814	811	812	811	811	810	809	810	810	809	810	811
2	809	808	810	806	806	788	764	730	728	722	730	773
3	709	711	709	707	698	692	693	704	685	690	660	696
4	664	671	666	667	665	651	651	649	650	650	647	657
5	644	643	640	640	638	638	635	634	635	633	631	637
6	630	630	629	627	628	628	625	621	618	618	615	624
7	470	463	469	465	825	824	826	825	822	821	821	694

Day 1 starts with the highest TDS levels, consistently averaging 811 ppm, indicating a stable nutrient concentration. Day 2 shows a slight decrease, with an average of 773 ppm. Days 3 to 6 show a steady decline in TDS levels, with averages decreasing from 696 ppm on Day 3 to 624 ppm on Day 6, reflecting a potential reduction in nutrient availability or water evaporation. Day 7 displays an irregular pattern, with lower TDS levels during the morning (averaging around 465 ppm) but a sharp spike in the afternoon, peaking at 826 ppm, leading to a daily average of 694 ppm. This significant fluctuation could suggest an issue such as nutrient imbalance or external contamination. Overall, TDS levels generally decrease over the week, except for Day 7's anomaly, which requires closer monitoring to ensure optimal conditions for hydroponic growth.

Table 4.6 Data Water Level for 7 Days (20/12/2024 - 26/12/2024)

Data Water level (%)												
Time Day	6:00 AM	8:00 AM	10:00 AM	12:00 AM	2:00 PM	4:00 PM	6:00 PM	8:00 PM	10:00 PM	12:00 AM	2:00 AM	Average
1	100	100	98	95	92	88	87	87	87	86	86	91
2	85	85	85	85	84	84	84	83	83	82	82	84
3	80	81	81	80	79	80	79	79	78	77	78	79
4	74	74	73	73	72	73	72	71	71	71	70	72
5	65	65	64	64	63	64	62	62	61	61	61	63
6	56	54	56	55	53	53	52	52	52	50	50	53
7	78	79	78	76	76	74	74	73	71	71	71	75

The table shows the water level percentages for a solar-powered hydroponic system over 7 days, measured at 12 intervals daily. On Day 1, water levels start at 100% and gradually decrease to 86%, with an average of 91%, the highest across all days. From Days 2 to 6, water levels steadily decline, with averages dropping from 84% on Day 2 to 53% on Day 6, the lowest. Day 7 shows an improvement, starting at 78% and ending at 70%, likely due to water replenishment. Overall, the water levels show a consistent downward trend, reflecting plant usage and system losses. To maintain optimal levels, regular water replenishment and monitoring are recommended, especially as levels approach critical lows, such as on Day 6. Using automation or alerts can help ensure stable water supply for healthy plant growth.

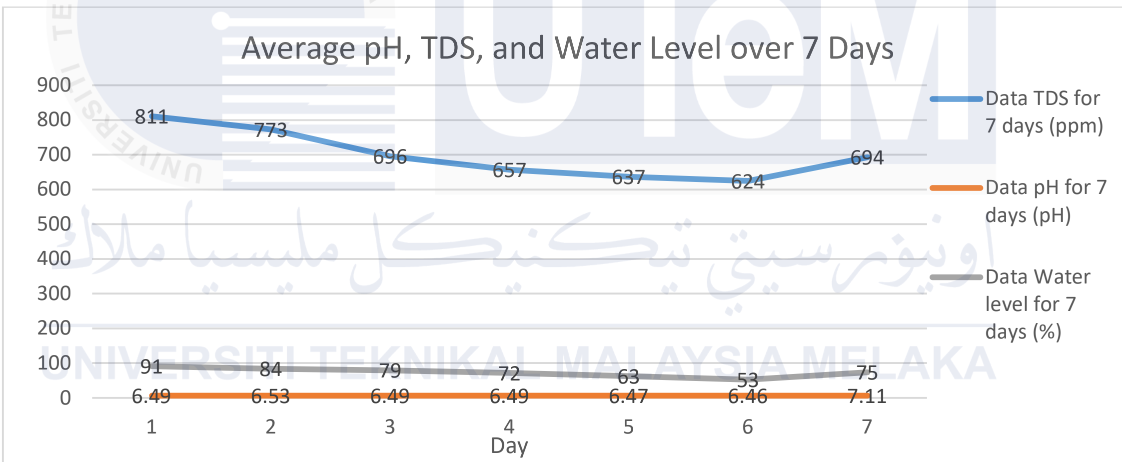

Figure 4.20 Graph Average Value for PH, TDS and Water Level

The graph shows the average pH, TDS (Total Dissolved Solids), and water levels over seven days. TDS starts high at 811 ppm on Day 1, decreases steadily to 624 ppm by Day 6, then spikes to 694 ppm on Day 7, likely due to nutrient replenishment. Water levels drop consistently from 91% on Day 1 to 53% on Day 6, indicating water usage by plants, then rise to 75% on Day 7, suggesting water was added. The pH remains stable between 6.46 and 6.53 for six days, but increases to 7.11 on Day 7, possibly due to water or nutrient adjustments. Regular monitoring and adjustments of pH, water, and nutrients are recommended to maintain optimal conditions.

4.2.4 Solar Panel

Table 4.7 Average Data Solar Panel over 7 Days (23/12/2024 - 29/12/2024)

Data Solar Panel : Average over 7 days				
Time	Irradiance, (W/m2)	Voltage, V	Current, A	Power, W
7:00 AM	16.55	13.06	0.23	3.0038
8:00 AM	65.47	15.77	0.28	4.4148
9:00 AM	141.40	17.21	0.30	5.1352
10:00 AM	182.90	18.17	0.32	5.8461
11:00 AM	364.43	18.85	0.34	6.4718
12:00 AM	453.43	18.71	0.35	6.6099
1:00 PM	399.43	18.48	0.34	6.2822
2:00 PM	258.71	18.47	0.35	6.4943
3:00 PM	160.77	18.19	0.33	5.9407
4:00 PM	93.73	17.50	0.32	5.5116
5:00 PM	47.44	16.73	0.28	4.7414
6:00 PM	33.44	15.97	0.29	4.5527
7:00 PM	11.33	12.99	0.24	3.1619

The table presents the average solar panel performance data over seven days, including irradiance (W/m²), voltage (V), current (A), and power (W) at different times of the day. The irradiance increases from 7:00 AM (16.55 W/m²) to peak at 12:00 PM (453.43 W/m²), and then gradually declines to 11.33 W/m² by 7:00 PM. Voltage follows a similar trend, starting at 13.06 V at 7:00 AM, peaking at around 18.85 V at 11:00 AM, and then decreasing in the evening. The current remains relatively stable during peak irradiance hours, ranging between 0.34 A and 0.35 A, and drops to 0.23 A in the early morning and evening.

Power output increases with irradiance, reaching its maximum of 6.6099 W at 12:00 PM and decreasing in the afternoon and evening. This data suggests the solar panel performs best during midday when irradiance is highest, aligning with the solar intensity curve. Efficient energy harvesting occurs between 10:00 AM and 3:00 PM, where both irradiance and power are consistently high. This highlights the importance of positioning and timing for maximizing solar energy generation.

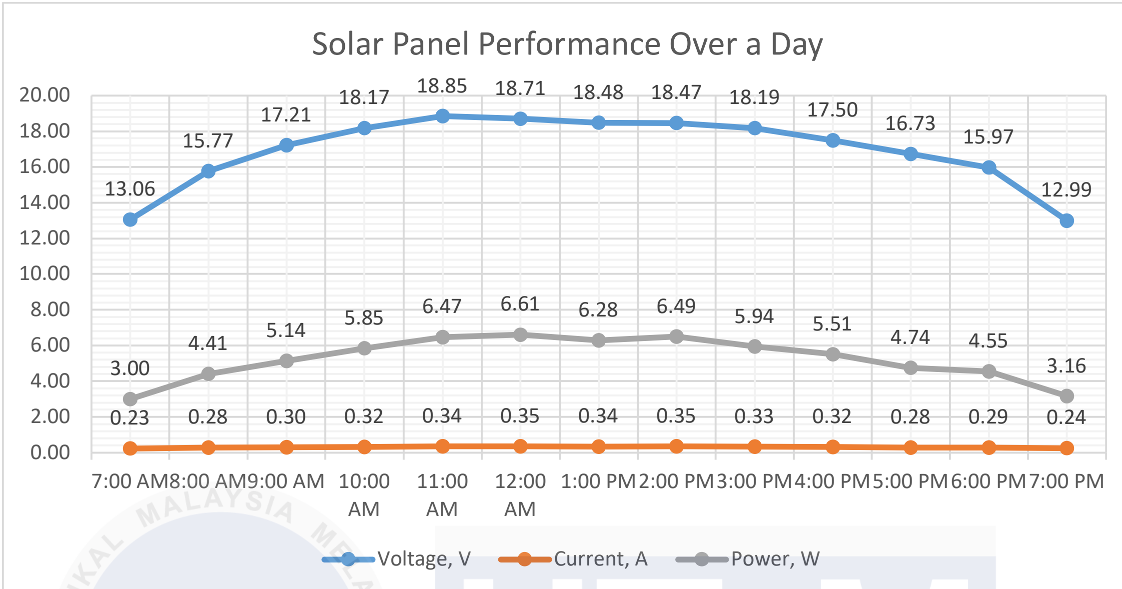

Figure 4.21 Graph Voltage vs Current vs Power

The graph shows the performance of a solar panel throughout the day. Voltage, current, and power increase steadily in the morning, peak around noon, and decrease in the evening. The highest power output occurs at 12:00 PM (6.61 W), when sunlight is strongest. Voltage remains stable during peak hours, while current and power closely follow sunlight intensity. The solar panel performs best around midday and reduces output during the early morning and late afternoon due to lower sunlight.

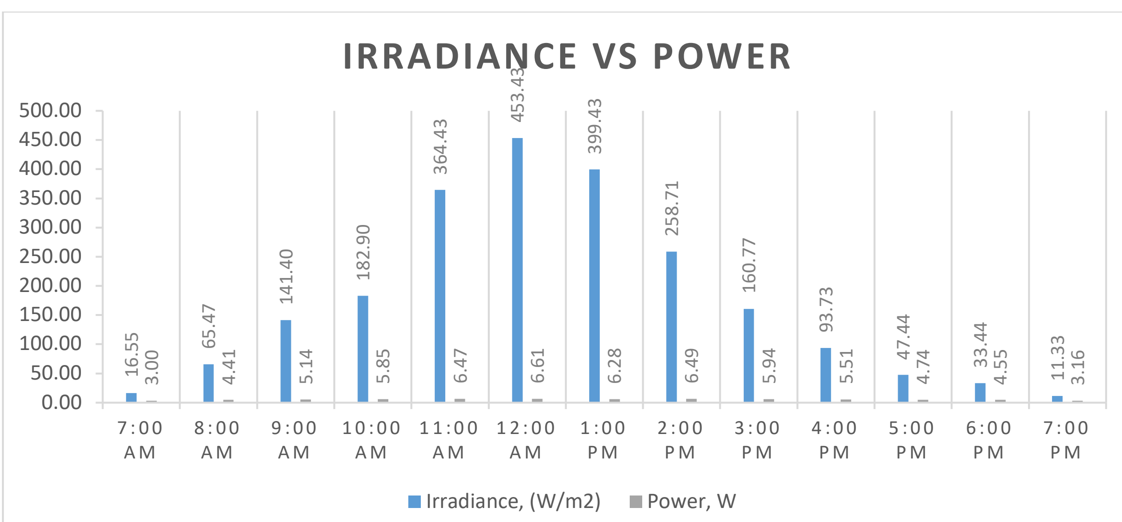

Figure 4.22 Irradiance vs Power

The graph compares solar irradiance (W/m²) and power output (W) throughout the day. Both irradiance and power increase in the morning, peaking at midday when sunlight is strongest. The highest irradiance occurs at 12:00 PM (453.43 W/m²), corresponding to the highest power output of 6.61 W. After noon, both values decline steadily as sunlight decreases. The trend indicates that power generation closely depends on irradiance levels, with stronger sunlight producing more power and don't forget the temperature of the solar panel module also needs to be taken into account because theoretically when the module solar panel temperature increases, the voltage will decrease.

4.2.5 Storage Battery

This analysis evaluates the feasibility of using a 12V, 300mA water pump powered by a 7.2Ah rechargeable sealed lead-acid battery for continuous operation over a 24-hour period. The calculations include discharge characteristics, recharge time, and the potential integration of a solar panel for continuous operation.

Table 4.8 Discharge and Recharge

Test	Date	Start			End			
		Time	Voltage (V)	Battery percentage (%)	Time	Voltage (V)	Battery Percentage (%)	Time Taken
Discharge	21/12/2024	11:00 AM	12.4V	90%	5:00 PM	11.4V	10%	6 hours
Recharge	22/12/2024	11:00 AM	11.4V	10%	5:00 PM	12.6	100%	6 hours

Discharge Analysis:

The current drawn by the water pump is determined using the formula:

$$I = \frac{P}{V}$$

Where:

- P=3.6WP (power of the pump),
- V=12V (battery voltage).

The current drawn by the pump is:

$$I = \frac{3.6}{12} = 0.3A$$

For continuous operation over 24 hours, the total capacity required is:

$$\text{Capacity Required (Ah)} = \text{Current (A)} \times \text{Time (hours)} = 0.3 \times 24 = 7.2\text{Ah}$$

The 12V, 7.2Ah battery matches this capacity exactly. However, to prolong battery life, it is recommended to use only 90% of the battery's capacity, leaving a 10% safety margin. The usable capacity at 90% depth of discharge (DoD) is:

$$\text{Usable Capacity (Ah)} = 90\% \times 7.2 = 0.9 \times 7.2 = 6.48\text{Ah}$$

The maximum discharge time without recharging is:

$$\text{Discharge Time (hours)} = \frac{\text{Usable Capacity (Ah)}}{\text{Load Current (A)}} = \frac{6.48}{0.3} \approx 21.6\text{hours}$$

This means the battery can power the pump for approximately 21 hours and 36 minutes before reaching 90% DoD.

Recharge Analysis:

The battery must be recharged during the 24-hour operation to sustain continuous use. Assuming a solar panel with a maximum charging current of 6A and a charging efficiency of 85%, the recharge characteristics are as follows:

1. Effective Capacity: The effective capacity required to recharge the battery is:

$$Effective\ Capacity\ (Ah) = \frac{\text{Battery Capacity (Ah)}}{\text{Efficiency}} = \frac{7.2}{0.85} \approx 8.47\text{Ah}$$

2. Recharge Time: The time to fully recharge the battery is :

$$\text{Recharge Time (hours)} = \frac{\text{Effective Capacity (Ah)}}{\text{Charging Current (A)}} = \frac{8.47}{6} \approx 1.41\text{hours}$$

Therefore, the battery can be fully recharged in approximately 1 hour and 25 minutes under ideal solar charging conditions.

This indicates that the 12V, 7.2Ah battery can power the 300mA water pump for approximately 21 hours and 36 minutes when discharged to 90% of its capacity. To sustain continuous operation for 24 hours, solar charging is required. A solar panel with a maximum charging current of 6A can fully recharge the battery within 1 hour and 25 minutes under ideal sunlight conditions.

To ensure uninterrupted operation, it is recommended to incorporate solar recharging during the day or upgrade to a higher-capacity battery. This solution guarantees reliable performance for smart farm applications while preserving battery health and longevity.

4.2.6 Energy Consumption Analysis

This analysis focuses on calculating the daily energy consumption of two water pumps along with other components in the hydroponic system.

1. Energy Consumption for the Water Pumps:

a) Pump 1 (24/7 Operation)

Pump 1 operates continuously for 24 hours with a power rating of 4.5 W. The energy consumption is calculated as:

$$E1 = P \cdot t$$

$$E1 = 4.5 \cdot 24 = 108Wh$$

b) Pump 2 (Short Operation)

Pump 2 operates for 10 seconds, twice a day. The total runtime per day is:

$$t = \frac{20s}{3600s/hr} = 0.00556hours$$

The energy consumed by Pump 2 is:

$$E2 = P \cdot t$$

$$E2 = 4.5 \cdot 0.00556 = 0.025Wh$$

2. Total Energy Consumption of the Water Pumps:

The total energy consumption of both pumps is:

$$Epumps = E1 + E2$$

$$Epumps = 108 + 0.025 = 108.025Wh$$

3. Buck Converter Efficiency:

The buck converter has an efficiency of 90%90\%90%, meaning it requires additional input energy to deliver the output energy. The input energy required is calculated as:

$$Ebuck\_in = \frac{Epumps}{Efficiency}$$

$$Ebuck\_in = \frac{108.025}{0.9} = 120.03Wh$$

4. Total Energy Consumption:

In addition to the water pumps, other components consume energy, which was previously calculated a $Eother = 26.76Wh$.

The total daily energy consumption is:

$$Etotal = Eother + Ebuck_{in}$$

$$Etotal = 26.76 + 120.03 = 146.79Wh$$

Table 4.9 Analysis Summary

Component	Energy Consumption (Wh)
Pump 1 (24/7)	108
Pump 2 (20 seconds daily)	0.025
Buck Converter Losses	12.005
Other Components	26.76
Total Daily Energy	146.79

The total energy consumption of the system is 146.79 Wh/day, accounting for the water pumps, buck converter efficiency losses, and other components. This information is essential for sizing the battery and solar panel to ensure uninterrupted operation of the system.

4.2.7 Calculate the Power Generation and Storage Capacity of The Solar System

The power generation and storage capacity of the solar system for the hydroponic system are calculated based on the specifications of the solar panels and batteries.

1. Solar Panels:

- Number of Panels: 1
- Power Rating per Panel: 100W
- Peak Sun Hours (PSH): 5 hours

The total power generation from the solar panels is determined using the formula:

$$Power = Power\ Rating\ per\ Panel \times Number\ of\ Panels$$

$$Power = 100W \times 1 = 100W$$

The total energy generated per day by the solar panels is calculated as:

$$Energy = Power \times Peak\ Sun\ Hours$$

$$Energy = 100W \times 5hours = 500watt - hours\ or\ 0.5\ kWh$$

2. Batteries:

- Number of Batteries: 1
- Voltage: 12V
- Amp-Hour Rating per Battery: 7.2Ah

The total energy storage capacity of the battery system is determined using the formula:

$$Energy = Voltage \times Amp - Hour\ Rating\ per\ Battery \times Number\ of\ Batteries$$

$$Energy=12V\times7.2Ah\times1=86.4watt\text{-}hours\ or\ 0.0864\ kWh$$

Analysis:

1. Daily Energy Generation:

   The solar panels generate approximately 500 watt-hours (0.5 kWh) of energy per day under ideal sunlight conditions. This energy is sufficient to power various components of the hydroponic system, assuming energy consumption does not exceed this limit.

2. Battery Storage Capacity:

   The battery system has a storage capacity of 86.4 watt-hours (0.0864 kWh). This capacity is significantly smaller than the daily energy generation, indicating that the battery can store only a fraction of the energy produced by the solar panels.

3. System Efficiency and Design Implications:

   Since the battery storage capacity is limited, most of the energy generated by the solar panels may remain unused unless additional batteries or energy storage solutions are incorporated. The solar panel's daily output far exceeds the storage capability of the current battery system.

The solar panels generate approximately 0.5 kWh of energy per day, while the battery system can store only 0.0864 kWh of energy. To maximize energy utilization, it is recommended to either:

- Add more batteries to increase storage capacity, or
- Use the energy directly during the day to power the hydroponic system components, reducing reliance on stored energy.

This analysis highlights the need for a balanced system design to optimize energy generation, storage, and consumption for efficient operation of the hydroponic system.

4.2.8 Performance of The Hydroponics and Monitoring System

Here's a structured table and analysis for evaluating the performance of the hydroponics and monitoring system based on Responsiveness, Effectiveness, and Reliability:

Table 4.10 Performance and Monitoring Hydroponic System Evaluation

No	Factors	Evaluation
1	Reliability	- Components operate reliably with minimal maintenance. - Backup battery ensures operation during power outages. - Occasional IoT connectivity interruptions may impact performance.
2	Responsiveness	- Sensors provide real-time parameter updates in the Blynk app. - System control (on/off) through the app is prompt but dependent on network strength.
3	Effectiveness	- Environmental monitoring (pH, TDS, temperature) is accurate and effective. - Solar power reduces operating costs and supports sustainability. - Limited advanced monitoring due to cost and scalability constraints.

4.2.8.1 Analysis for Reliability, Responsiveness and Effectiveness

- Reliability: The system is highly reliable due to its robust components and backup power system, ensuring consistent operation. However, occasional IoT connectivity interruptions could affect its monitoring capabilities, particularly in areas with unstable networks.
- Responsiveness: The system offers good responsiveness by providing real-time updates through the Blynk app and enabling prompt on/off control. However, it depends on stable network connectivity for optimal performance, which may cause delays in less reliable network environments.
- Effectiveness: The system effectively monitors key environmental parameters such as pH, TDS, and temperature, ensuring optimal plant growth. The integration of solar power enhances cost efficiency and sustainability. However, advanced monitoring

features like ammonia or nitrate levels are not included due to sensor cost and complexity, limiting its application for more specialized setups.

The hydroponic monitoring and control system is a reliable, responsive, and effective solution for managing plant growth in small to mid-scale setups. Its robust components and backup battery ensure consistent operation, while solar power integration reduces costs and supports sustainability. The system provides real-time monitoring of key parameters such as pH, TDS, and temperature through the Blynk app, with prompt on/off control capabilities. However, its reliance on stable network connectivity can occasionally cause delays, and the absence of advanced monitoring features like ammonia or nitrate levels limits its application for specialized or large-scale farming. Overall, the system offers a practical and efficient approach to modern hydroponic agriculture.

4.3 Blynk Application Interface

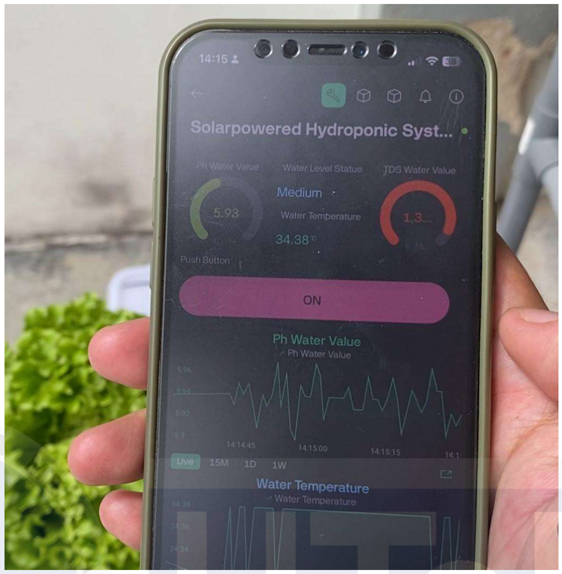

Figure 4.23 Blynk Application Interface Display

The Blynk app interface for the Solar-Powered Hydroponic System provides a comprehensive and user-friendly platform for monitoring and controlling essential parameters in real-time. The main dashboard displays key readings such as the pH Water Value 5.93, which helps track the acidity or alkalinity of the nutrient solution, the Water Level Status "Medium", which indicates the reservoir's water level, and the Water Temperature 34.38°C, which is critical for maintaining suitable conditions for plant growth. Additionally, the TDS Nutrient Value 648 is shown, representing the Total Dissolved Solids in the nutrient solution, ensuring the correct concentration of nutrients for plant health.

The interface also features interactive graphs for tracking historical trends, including the pH Water Value Graph, the Water Temperature Graph, and a newly added TDS Nutrient Value Graph, providing insights into nutrient levels over time. These graphs help users analyze fluctuations and make data-driven decisions for optimal system performance. A prominent "ON" button allows manual control of system components, such as pumps or lights, providing added flexibility. The app also supports live monitoring, with real-time updates on all key parameters. This streamlined interface ensures effective management of the hydroponic system, making it easier to maintain consistent environmental conditions and optimize plant growth.

4.4 Liquid-Crystal Display (LCD)

Figure 4.24 LCD Display

The LCD screen on the hydroponic system provides real-time updates on key operational parameters essential for maintaining optimal plant growth. It indicates the system's status as "ON," confirming that the system is currently operational. The water level is displayed as "WL: Medium," ensuring the reservoir has an adequate amount of water for circulation. The pH value is shown as 6.4, which falls within the ideal range for nutrient absorption. The TDS value is recorded at 648, reflecting the nutrient concentration in the water solution. Additionally, the water temperature (T.W.T.) is displayed as 29.4°C, providing insight into the water's thermal conditions, critical for plant health. Lastly, the screen displays humidity (HUMI) at 49.0, offering information about the surrounding environmental conditions. This LCD interface allows for convenient on-site monitoring, enabling users to assess the system's performance and adjust if necessary.

Summary

This chapter presents the performance analysis of the hydroponic system over seven days, focusing on key metrics such as water temperature, humidity, pH, TDS, water levels, solar energy generation, and lettuce growth rates. The system maintained stable environmental conditions suitable for lettuce growth, though some fluctuations in pH and TDS values required adjustments. Solar panels provided sufficient energy to power the system, with peak efficiency during midday. Lettuce exhibited steady growth, with an average increase in leaf size over four weeks. Performance evaluations highlight the system's reliability, responsiveness, and effectiveness in monitoring and controlling parameters. Limitations include dependency on stable IoT connectivity and constraints in advanced monitoring features. Overall, the system demonstrated its feasibility and potential for sustainable hydroponic farming in small to medium-scale applications.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The development of a solar-powered hydroponic system using the Blynk app offers a sustainable, innovative solution to address key challenges in modern agriculture, particularly for small-scale and urban farmers. This project integrates renewable energy, efficient water and nutrient management, and smart technology to create a resilient farming system. It advances Sustainable Development Goals (SDGs), including Zero Hunger (SDG 2), Affordable and Clean Energy (SDG 7), and Industry, Innovation, and Infrastructure (SDG 9).

By leveraging solar energy, the system reduces environmental impact and operational costs, while the Blynk app enables real-time monitoring and control, enhancing precision and productivity. This technology empowers marginalized communities by improving access to fresh, nutritious food and promoting inclusive, sustainable farming practices. The project also addresses global challenges such as food security, climate change, and health disparities, contributing to a more equitable and sustainable food system.

In conclusion, this solar-powered hydroponic system demonstrates the potential of combining renewable energy and smart technologies to revolutionize agriculture, making it more efficient, environmentally friendly, and accessible to all.

5.2 Project Potential

The "Solar-Powered Hydroponic System Using Blynk App" demonstrates significant potential for commercialization, practical applications, and meeting community needs:

1. Commercialization Potential:

- The system offers an energy-efficient and cost-effective solution for urban and small-scale farmers, making it highly marketable in urban agriculture and sustainability sectors.
- Its integration with the Blynk app and IoT technology aligns with the growing demand for smart farming solutions, appealing to tech-savvy consumers and agricultural businesses.
- The system's modular design allows scalability, catering to both individual home growers and larger commercial enterprises.
- Customization options, such as additional sensors and AI integration, can attract different market segments, including educational institutions, research centers, and industrial hydroponic farms.

2. Practical Applications:

- Provides a reliable method for growing fresh produce in urban areas with limited space and resources, addressing the challenges of food deserts and high transportation costs for fresh food.
- Reduces dependence on traditional farming, making it suitable for regions with adverse climate conditions or water scarcity.
- The system's automation and remote monitoring features simplify operations, making it ideal for users with minimal farming experience.

- Facilitates sustainable and efficient farming by reducing water usage, minimizing energy costs, and enabling year-round crop production.

3. Community Needs:

- Empowers marginalized communities by increasing access to fresh, nutritious food and supporting local food systems.
- Promotes sustainable farming practices, contributing to environmental conservation and climate resilience.
- Provides an educational platform for teaching hydroponic farming, renewable energy, and IoT applications to students and community members.
- Addresses urban unemployment by creating opportunities for small-scale entrepreneurs and enabling community farming initiatives.
- Enhances food security and self-reliance in both urban and rural areas, helping communities cope with economic and environmental challenges.

Overall, the project has the potential to transform urban farming and contribute to sustainable development by addressing key community needs, providing practical solutions, and offering a viable pathway for commercialization.

5.3 Future work

For the future work:

i. We can work with hydroponic education and outreach by develop educational programs and resources to raise awareness about hydroponic system and its benefits.

ii. Implement advanced energy management systems to optimize the usage of solar power and battery storage.

iii. Develop advanced water recycling and filtration systems to further minimize water usage and waste.

iv. Add two water pumps for fertilizer A and fertilizer B for the fertilizer water pump according to the correct ratio into the main tank when the total dissolved solids sensor detects a value less than the specified value

v. Explore the implementation of other hydroponic methods, such as aeroponics or deep-water culture, to diversify the system's capabilities and efficiency.

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APPENDICES

Appendix A Project Planning BDP 1

PROJECT PLANNING BDP 1														
	2024													
Project Activity	01	02	03	04	05	06	07	08	09	10	11	12	13	14
FYP														
Proposal Project														
• Meet Supervisor														
• Decide Title of Project														
• Write an Abstract	B													
• Research journal	D													
Chapter 1	P													
• Begin Chapter 1														
• Project background	B													
• Discussio n with supervisor	R													
	I													
Chapter 2	E													
• Begin Chapter 2	F													
• Hydroponic method study	I													
• Journal study	N													
• Discussion with supervisor	G													
Chapter 3														
• Software research														
• Hardware decision														
• Supervisor approval														
Chapter 4														
• Project design														
• Circuit design														
• Analysis of component														
Presentation Slide														

Appendix B Project Planning BDP 2

PROJECT PLANNING BDP 2														
	2024													
Project Activity	01	02	03	04	05	06	07	08	09	10	11	12	13	14
FYP														
Meet SV discuss about planning PSM 2.														
Explain to SV things to buy to proceed build project.														
Do the claim form for PSM expenses.														
Proceed to do the coding for this project.														
Proceed to do the circuit of the project and implement the code into circuit.														
Develop the hydroponic system of the project.														
Present result of the project to SV and do some improvement														
Collect data for analysis.														
Proceed to complete PSM 2 reports.														
Prepare for presentation with do poster for PSM 2														

Appendix C Coding for Hydroponic System

```
#define BLYNK_TEMPLATE_ID
"TMPL60MQgUYbc"
#define BLYNK_TEMPLATE_NAME
"Solarpowered Hydroponic System Using Blynk
App FYP"
#define BLYNK_AUTH_TOKEN "dZ-
R6HAuxuXLDTfx-e1TARg8JwymLy3P"
#define BLYNK_PRINT Serial

#include <WiFi.h>
#include <BlynkSimpleEsp32.h>
#include <OneWire.h>
#include <DallasTemperature.h>
#include <DHT.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

// WiFi credentials
char ssid[] = "aariq";
char pass[] = "acap1234";

// Pin definitions
const int pH_Pin = 34;
const int TDS_Pin = 35;
const int Water_Level_Pin = 32;
const int Pump_Pin = 25;
const int Extra_Pump_Pin = 26;
const int LDR_Pin = 36;
const int Temp_Pin = 4;
const int DHT_Pin = 27;

// Constants for calibration
float voltageReference = 3.3;
float pH_CalibrationOffset = 0.0;
float waterLevelMin = 0;
float waterLevelMax = 4095;
float temperatureCalibrationOffset = 3.0;
float humidityCalibrationOffset = 20;

// Initialize OneWire and DallasTemperature
OneWire oneWire(Temp_Pin);
DallasTemperature sensors(&oneWire);

// Initialize DHT sensor
#define DHTTYPE DHT22
DHT dht(DHT_Pin, DHTTYPE);
// Initialize LCD
LiquidCrystal_I2C lcd(0x27, 20, 4);
BlynkTimer timer;
```

```
// Define system state variable
bool systemState = false;

void setup() {
  Serial.begin(115200);
  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);

  pinMode(Pump_Pin, OUTPUT);
  pinMode(Extra_Pump_Pin, OUTPUT);

  // Set all pumps to OFF (HIGH for active-low
relay)
  digitalWrite(Pump_Pin, HIGH);
  digitalWrite(Extra_Pump_Pin, HIGH);

  // Start the DS18B20 temperature sensor
  sensors.begin();
  // Start the DHT22 sensor
  dht.begin();

  // Initialize the LCD
  lcd.init();
  lcd.backlight();
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("System Initializing...");
  delay(2000);
  lcd.clear();

  timer.setInterval(1000L, manageSystem);
}

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

// Blynk function to control the whole system
(On/Off)
BLYNK_WRITE(V3) {
  systemState = param.asInt();

  if (systemState) {
    digitalWrite(Pump_Pin, LOW);
    lcd.setCursor(6, 0);
    lcd.print("ON ");
    Serial.println("System ON - Main Pump ON");
  } else {
    digitalWrite(Pump_Pin, HIGH);
```

```
digitalWrite(Pump_Pin, HIGH);
    digitalWrite(Extra_Pump_Pin, HIGH);
    lcd.setCursor(6, 0);
    lcd.print("OFF");
    Serial.println("System OFF - All Pumps OFF"); }
}
// Function to monitor sensors and control pumps
void manageSystem() {
  if (!systemState) {
    digitalWrite(Pump_Pin, HIGH);
    digitalWrite(Extra_Pump_Pin, HIGH);
    return; }
  // Read Water Level sensor value
  int waterLevelValue =
analogRead(Water_Level_Pin);
  float waterLevelPercentage =
(float(waterLevelValue) - waterLevelMin) /
(waterLevelMax - waterLevelMin) * 100;
  // Determine water level status
  String waterLevelStatus;
  if (waterLevelPercentage < 20) {
    waterLevelStatus = "Low";
    digitalWrite(Extra_Pump_Pin, LOW);
    Serial.println("Water Level Low - Extra Pump
ON");
  } else if (waterLevelPercentage < 50) {
    waterLevelStatus = "Medium";
    digitalWrite(Extra_Pump_Pin, HIGH);
  } else {
    waterLevelStatus = "High";
    digitalWrite(Extra_Pump_Pin, HIGH);
  }
  readSensorsAndSendData(waterLevelPercentage,
waterLevelStatus);
}
void readSensorsAndSendData(float
waterLevelPercentage, String waterLevelStatus) {
  // Read pH sensor value
  int pH_Value = analogRead(pH_Pin);
  float pH_Voltage = (pH_Value / 4095.0) *
voltageReference;
  float pH_Level = 2.8 * pH_Voltage +
pH_CalibrationOffset;
  // Read TDS sensor value
  int TDS_Value = analogRead(TDS_Pin);
  float TDS_Voltage = (TDS_Value / 4095.0) *
voltageReference;
float TDS_Level = (TDS_Voltage /
voltageReference) * 1950;
```

```
  // Read LDR sensor value
  int LDR_Value = analogRead(LDR_Pin);
  // Determine light conditions based on LDR
reading
  String lightStatus;
  if (LDR_Value < 1024) {
    lightStatus = "Bright";
  } else if (LDR_Value < 2048) {
    lightStatus = "Cloudy"; } else {
    lightStatus = "Dark";}
  // Read temperature from DS18B20 sensor
  sensors.requestTemperatures();
  float waterTemperature =
sensors.getTempCByIndex(0);
  waterTemperature -=
temperatureCalibrationOffset;
  float controlBoxHumidity =
dht.readHumidity();
  if (isnan(controlBoxHumidity)) {
    controlBoxHumidity = 0.0;}
    controlBoxHumidity -=
humidityCalibrationOffset;
  // Display data on LCD
  lcd.setCursor(0, 0);
  lcd.print("System:    ");
  lcd.print(systemState  ? "ON" : "OFF");
  lcd.setCursor(0, 1);
  lcd.print(" PH: ");
  lcd.print(pH_Level, 1);
  lcd.setCursor(0, 2);
  lcd.print("TDS: ");
  lcd.print(TDS_Level, 1);
  lcd.setCursor(10, 1);
  lcd.print("WLvl: ");
  lcd.print(waterLevelStatus);
  lcd.setCursor(0, 3);
  lcd.print("TWt: ");
  lcd.print(waterTemperature, 1);
  lcd.setCursor(10, 2);
  lcd.print("WCon: ");
  lcd.print(lightStatus);
  lcd.setCursor(10, 3);
  lcd.print("Humi: ");
  lcd.print(controlBoxHumidity, 1);
  // Send data to Blynk
  Blynk.virtualWrite(V0, pH_Level);
  Blynk.virtualWrite(V1, TDS_Level);
  Blynk.virtualWrite(V2, waterLevelStatus);
  Blynk.virtualWrite(V10,
waterTemperature);}
```