Faculty of Electrical Technology and Engineering

DEVELOPMENT OF SOLAR WATER QUALITY MONITORING SYSTEM WITH IOT FOR FISH FARMING

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Bachelor of Electrical Engineering Technology with Honours

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DEVELOPMENT OF SOLAR WATER QUALITY MONITORING SYSTEM WITH IOT FOR FISH FARMING

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

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Supervisor Name : Ts. Dr. Suziana Binti Ahmad

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DEDICATION

To my beloved and supportive mother,
NORIZAM BINTI MUSTAFA
Thank you for your endless support in caring for me physically and mentally, loving me wholeheartedly and providing everything I needed without hesitation.

My project supervisor,
TS. DR. SUZIANA BINTI AHMAD
Thousands of gratitude for the lesson and guidance throughout the process of completing this project.

To all my friends,
Thank you for the unlimited support and guidance contributing to completing this project. I wish you all happiness in your life.

ABSTRACT

Nowadays, solar is one of the most attractive renewable energies to use at home, the office, or other places and items that require electricity. This project is purposely designed to implement the solar water quality monitoring system with IoT for fish farming using solar panels as the main supply. Secondly, to fabricate the water quality monitoring system using an ESP32, IoT, and several types of sensors, which are pH sensors, temperature sensors, and TDS sensors. Lastly, the performance of the solar water quality monitoring system with IoT for fish farming will be analyzed using data measurements. This device will be used to collect water quality data for fish farming, and this device will also use solar panels to promote sustainability and cost-efficiency, with the potential to revolutionize aquaculture operations and pave the path for future advances in automated procedures based on real-time data insights. The data collected from these water samples is then analyzed using data and an accurate meter. Based on the previous result, the pH reading for good conditions for fish is 6.5 to 8.5. Meanwhile, the temperature readings should be from 25 °C to 32 °C, and the TDS readings should be from 0 PPM to 1000 PPM.

ABSTRAK

Pada masa kini, solar adalah salah satu tenaga boleh diperbaharui yang paling menarik untuk digunakan di rumah, pejabat, atau tempat dan barang lain yang menggunakan elektrik. Projek ini sengaja direka untuk melaksanakan sistem pemantauan kualiti air solar dengan IoT untuk penternakan ikan menggunakan panel solar sebagai bekalan utama. Kedua, untuk membuat sistem pemantauan kualiti air menggunakan ESP32, IoT, dan beberapa jenis sensor, iaitu sensor pH, sensor suhu, dan sensor TDS. Akhir sekali, prestasi sistem pemantauan kualiti air solar dengan IoT untuk penternakan ikan akan dianalisis menggunakan pengukuran data. Peranti ini akan digunakan untuk mengumpul data kualiti air untuk penternakan ikan, dan peranti ini juga akan menggunakan panel solar untuk menggalakkan kemampanan dan kecekapan kos, dengan potensi untuk merevolusikan operasi akuakultur dan membuka jalan untuk kemajuan masa depan dalam prosedur automatik berdasarkan nyata-wawasan data masa. Data yang dikumpulkan dari sampel air ini kemudiannya dianalisis menggunakan data dan meter yang tepat. Berdasarkan hasil sebelumnya, bacaan pH untuk keadaan yang baik untuk ikan ialah 6.5 hingga 8. Sementara itu, bacaan suhu hendaklah dari 25°C hingga 32°C, dan bacaan TDS hendaklah dari 0 PPM hingga 1000 PPM.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

%	-	Percentage
°	-	Degree
±	-	Plus-minus
≥	-	Greater than or equal

LIST OF ABBREVIATIONS

V	-	Voltage
A	-	Ampere
W	-	Power
Hz	-	Frequency

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

The sun serves as the principal source of energy for the Earth. Solar power is the most auspicious renewable energy source for electricity generation [1]. Hence, this project's primary electricity source is solar photovoltaic, ensuring both environmental sustainability and a perpetual supply of energy.

The value of fresh water in agriculture, industry, and human survival is undeniable. In the past few decades, aquaculture has experienced explosive growth all over the world, particularly in the developing nations of Asia, which are responsible for producing 89% of the world's total fish supply[1][2]. Agriculture is also one of the major sources of income in many countries like India, China, and others[3]. So, the high use of chemicals in manufacturing, construction, other industries, and the direct discharge of polluted water from industries into nearby water resources have significantly contributed to the deterioration of global water quality, which has become an important issue.

The development of solar water quality monitoring system with IoT for fish farming is the main purpose of this project. The most important thing in fish farming is water quality to involving fish health and performance in aquaculture production methods[4], [5]. Due to the ineffective water quality monitoring and delayed response to changes in quality factors like temperature and dissolved oxygen, fish will die and losses to the farmer due to low production. This project also uses some sensors to get temperature, pH, turbidity, and dissolved oxygen of water. IoT has been used because IoT can store, retrieving, and analyzing data as well as a communication technology that incorporates electronic system[6].

Finally, all data can be viewed in the mobile phone application. Thus, this system is used to ensure that the culturist will receive accurate data during the day as well as during the night without any need for time consuming and costly lab tests, manual water collection and it also improve Bio-Security factor of pond system as it prevents worker to the pond water contamination by careless workers which could gravely affect the fish[7].

1.2 Addressing Global Warming Through Weather Sensing Project

Solar water quality monitoring systems with IoT for fish farming solve several worldwide issues. Fish farming can pollute, spread diseases, and degrade ecosystems if not managed properly. So, a solar water quality monitoring system with IoT prevents these difficulties and supports sustainable aquaculture. This project also allows real-time monitoring and automatic control, optimizing water usage and conservation for fish farming. Sustainable aquaculture practices backed by solar water quality monitoring with IoT can also address food security. These systems produce seafood to fulfil the growing need for healthy protein by optimizing conditions and lowering losses. IoT in fish farming advances technology and rural development. Solar water quality monitoring systems in remote or off-grid regions give farmers real-time data and boost production, livelihoods, and rural economic growth. IoT-enabled technologies also enable data-driven decision-making and research. This data can reveal fish behavior, environmental trends, and disease prevention, improving fish farming practices. Finally, solar water quality monitoring systems can reduce glasshouse gas emissions, enhancing climate change resilience.

1.3 Problem Statement

Now, our environment has been polluted with fuel to produce electricity such as fossil fuels, coal, oil, and gas. The pollution will cause harmful greenhouse gas emissions, such as carbon dioxide[8]. Therefore, solar photovoltaic is one of the renewable energies that is very good to use cause the energy of electricity never runs out and it is key to addressing the climate crisis[9].

High amounts of pollutants in the water system affect humans, aquaculture, flora, and fauna. One of the causes of pollution in the water system is landslides and mud floods. Human population increase necessitates the development of additional water sources whose quality is unknown. So, water quality monitoring system is very important to us to prevent us from using dirty water and save our aquaculture production[2][10]

Nowadays, all people need something that can lighten their burden and make their daily work easier. Thus, IoT is one of the system capabilities that enables the transmission of a large amount of data over a network without requiring human-to-human or human-to-computer interaction, it may also decrease manpower and save time[11].

Fish farming is currently the fastest-expanding industry for producing animal food, and it will eventually provide more than half of the seafood consumed by people worldwide[12]. Lately, farmers have suffered losses due to production because the water quality in fish farming affects the longevity and freshness of the fish[13]. So, the farmer for fish farming must make sure the water quality is good to make sure the fish can be long-lasting and fresh when marketed, and the farmer will also gain profit in sales.

1.4 Project Objective

1. To implement the Solar Water Quality Monitoring System with IoT for fish farming using solar panels as the main supply.
2. To fabricate the Water Quality Monitoring System using ESP32, IoT, pH sensor, TDS sensor, and temperature sensor.
3. To analyze the performance of the Solar Water Quality Monitoring System with IoT for fish farming using data measurements.

1.5 Scope of Project

The project has a broad scope that focuses on sustainable methods and improved monitoring systems in the field of fish farming. First and foremost, solar power takes center stage as the major energy source, emphasizing the project's commitment to environmentally beneficial and sustainable energy solutions. This not only coincides with environmental concerns but also emphasizes the project's commitment to reducing its ecological imprint.

A sophisticated monitoring system developed to analyses water quality is a critical component of the program. Sensors are used in the system to measure critical parameters like temperature, pH levels, and TDS. This multidimensional method ensures a full understanding of the aquatic environment, allowing for exact modifications and interventions to maintain ideal fish farming conditions.

The detection system, which is a key component of the project, is controlled by the ESP32. This selection demonstrates the project's dedication to using cutting-edge technologies for efficient and accurate data processing. The Arduino UNO works in tandem with temperature, pH, and Total Dissolved Solids (TDS) sensors to establish a resilient network that continuously collects and analyses data to provide real-time insights into water quality.

Importantly, the fundamental goal of the initiative is to improve fish farming techniques through thorough water quality management. The research attempts to produce an optimal environment for fish growth and well-being by precisely addressing characteristics such as temperature, pH, and TDS. This integrated strategy not only ensures aquaculture's sustainability but also corresponds with the larger goal of fostering environmentally sensitive and technologically sophisticated agricultural solutions. In essence, the project is a harmonious combination of renewable energy, smart monitoring systems, and a concentrated focus on improving water quality for sustainable and efficient fish farming.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The quality of the water that countries have access to is one of the most significant challenges humans faces in the twenty-first century. Poor water quality poses a risk to human health, limits agricultural productivity, reduces the number of ecological services, and slows economic expansion[14]. Fresh water, which is defined as water with fewer than five hundred parts per million dissolved salts, is the embodiment of all living things on Earth. There are many different natural sources of fresh water, some of which include rivers, lakes, ponds, groundwater, cave water, springs, floodplains, and wetlands. Degradation of water quality directly impacts the economy, environment, and society. In addition, water pollution can be caused by several different factors, including domestic sewage and animal wastes, the careless use of pesticides, rapid industrial development, and urbanization[13]. These factors have resulted in an increased quantity and diversity of toxic and hazardous wastes, the long-term effects of which are still unknown regarding human health and ecosystems.

Meeting the food and nutritional demands of the thronging billions is one of the biggest difficulties facing the world today. With an ever-growing population as a backdrop, this challenge becomes more difficult. It is anticipated that by the year 2050, the present world population of 7.6 billion would have increased to 9.2 billion. If this scenario is not addressed directly, there will inevitably be a significant imbalance between supply and demand for food. The current level of food production needs to be boosted by 60-70 percent[15]. The Food and Agricultural Organization of the United Nations (FAO) lays out the strategy for guaranteeing food security, enhancing nutrition, eradicating hunger, and providing a balanced diet for the entire global populace[15]. Every member nation is urged to contribute to the achievement of this objective.

It is a well-known fact that 'aquaculture' can significantly contribute to achieving food security. So, fish farming is one way to solve this problem. Consequently, there is always a great demand for fish items on the market. When people examine the need on a global scale, the aggregate demand is very high, and this is the sector of animal feed production that is rising at the highest rate. Aquaculture, sometimes known as fish farming, is a type of farming in which fish are farmed in tanks and then sold for human consumption. Like fish hatcheries, fish farms have a capacity of over 500,000 fish. Aquatic animals are the healthiest and most affordable sources of animal protein. Aquatic animals also provide important vitamins, minerals, and omega-3 fatty acids, which are important dietary supplement[16]. In the animal-based food chain, farmed fish uses the least amount of land and resources compared to meat from chicken, beef, sheep, and goats.

2.1.1 Societal & global issue on solar water quality monitoring system with IoT for fish farming

The integration of solar water quality monitoring systems with the Internet of Things (IoT) holds significant promise for addressing critical societal and global challenges in the context of fish farming. As the demand for seafood rises to meet the needs of a growing global population, ensuring sustainable aquaculture practices becomes imperative. However, fish farming operations often face environmental, economic, and technological hurdles that hinder their long-term viability and contribute to negative ecological impacts. In this context, the adoption of solar water quality monitoring systems with IoT emerges as a potential solution with multiple benefits. By leveraging solar energy and IoT technology, these systems enable real-time monitoring and data-driven decision-making, thereby promoting efficient water management, reducing environmental impact, and enhancing the overall sustainability of fish farming practices.

2.2 Renewable Energy

Energy has always been an important topic in human history, and it almost always surrounds life. Even though coal, oil, and gas are widely used to make energy, oil reserves run out in 50 years, gas reserves last only 70 years, and coal reserves are completely gone in 200 years[17]. As a result, the quest for new energy sources is intensifying because current energy supplies are insufficient to support human life. Some nations adopt new energy policies and frame them by raising society's understanding of renewable energy to encourage eco-friendly energy usage. The primary goal of the energy strategy is to obtain energy through consistent, affordable, clean, and dependable means, in addition to expanding the sources[18].

In the modern world, reducing the greenhouse effect and increasing energy efficiency are difficult tasks. Besides that, global warming has been one of the most important problems in the world for a long time. Some of the clear effects of global warming are rising temperatures, the loss of icebergs, drought, and changes in ecosystems. This is caused by human actions, especially the use of fossil fuels, which is one of the main sources of carbon dioxide releases that add to global warming [19]. Most of the growth in energy use is because more people are driving and taking trains and buses. Oil is the most common fuel, and 94% of the energy used for transportation comes from oil.

Over two-thirds of the world's oil demand and about a quarter of the world's carbon dioxide pollution from burning fuel come from the transportation industry. Therefore, the greatest alternative to deal with this issue is renewable energy, which also helps to increase jobs in many nations, and this makes it possible for people or city inhabitants who live a long way from the city center to obtain amenities like gas, electricity, water, fuel, and others that are inaccessible via traditional transportation. Renewable energy or green energy comes from natural resources that can be used again and again, like sunshine, wind, waves, and geothermal[20]. The most popular renewable energy sources currently are solar energy, wind energy, biomass energy, tidal energy, and hydropower, as shown in Figure 2.1.

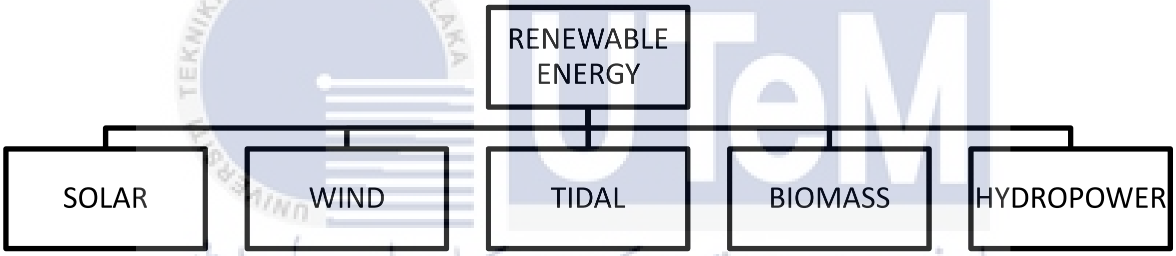


Figure 2.1 Renewable energy type

2.2.1 Solar Energy

In this age of science and technology, people are slowly getting more and more hungry for energy. Solar energy can help people reduce greenhouse gas pollution and the destruction of the ozone layer[21][22]. It is the way to make energy that is best for the earth. Solar energy is a fast-growing energy field right now because it can be used anywhere there is sunlight, and it doesn't hurt the earth. Now, less than one-tenth of one percent of the world's energy needs are met by this technology.

There are numerous types of solar panels that are typically used[23]. Monocrystalline solar panels are made from a single crystal structure of silicon and are known for being very efficient. It has smooth corners and a dark color that stays the same. Next, polycrystalline solar panels are made up of pieces of various silicon crystal. Compared to monocrystalline panels, polycrystalline panels are more cost-effective but have lower efficiency. Polycrystalline panels are typically square or rectangular in shape and have a bluish color. Lastly, thin-film solar panels are made by putting a thin layer of semiconductor material on a base. Even though thin-film solar panels are less efficient than crystalline panels and are lighter and more flexible, thin-fil also has benefits when it comes to being put on different surfaces, like roofs or building walls. Three types of solar panels are shown in Figure 2.2.

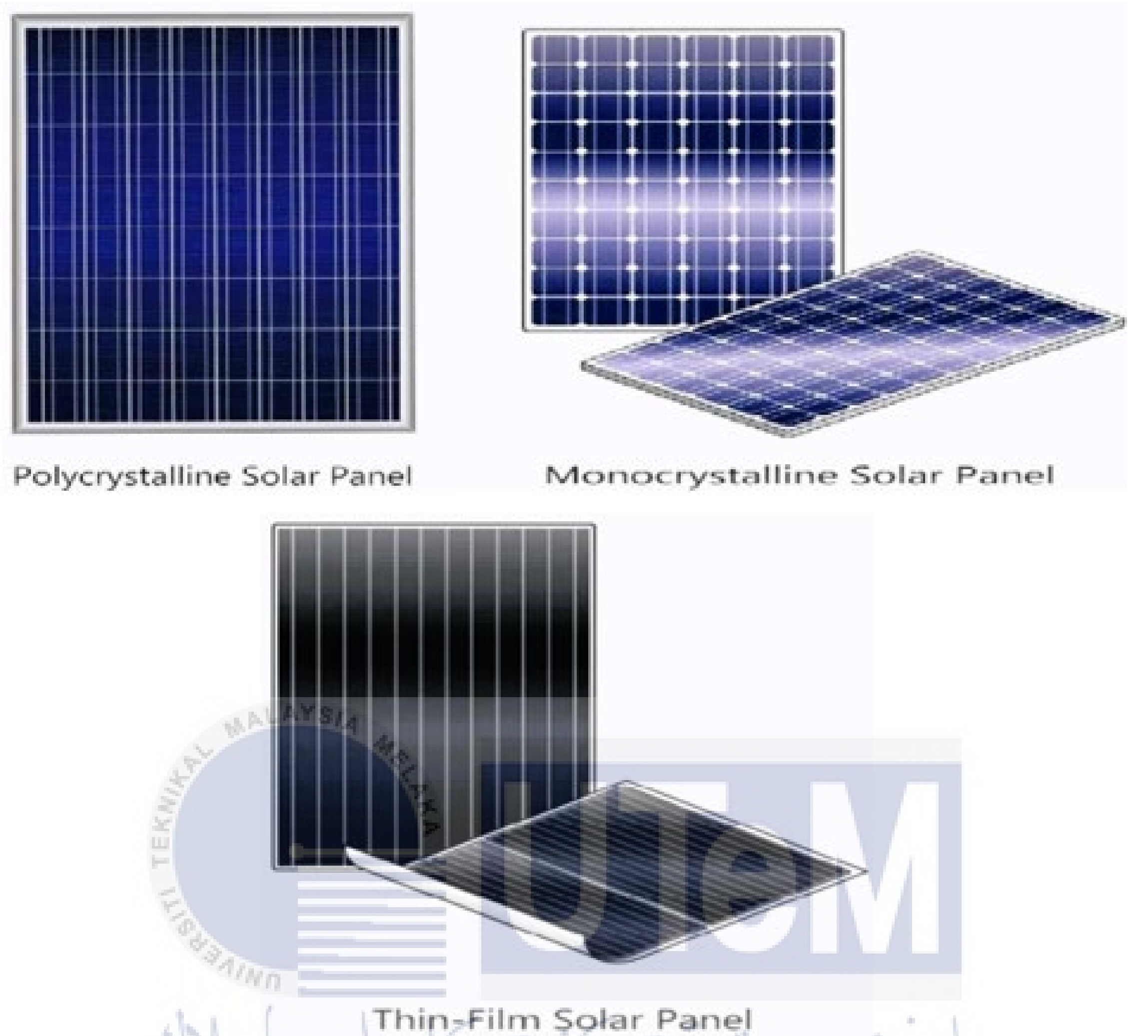


Figure 2.2 Various types of solar panels[9]

Photovoltaic cells are the most common type and are made from the same semiconductor components as computer chips. Solar panels are made up of photovoltaic (PV) cells, which are typically composed of silicon or other semiconductor materials. When sunlight hits the solar panel, the PV cells absorb the photons, which are particles of light energy, and then excite the electrons in the material. The suggested solar power system is depicted in a simplified form in Figure 2.3. The key parts are the 3kW solar PV array, solar charge controller, battery bank, and solar inverter. Connectivity between the various tracking and monitoring systems is also shown.

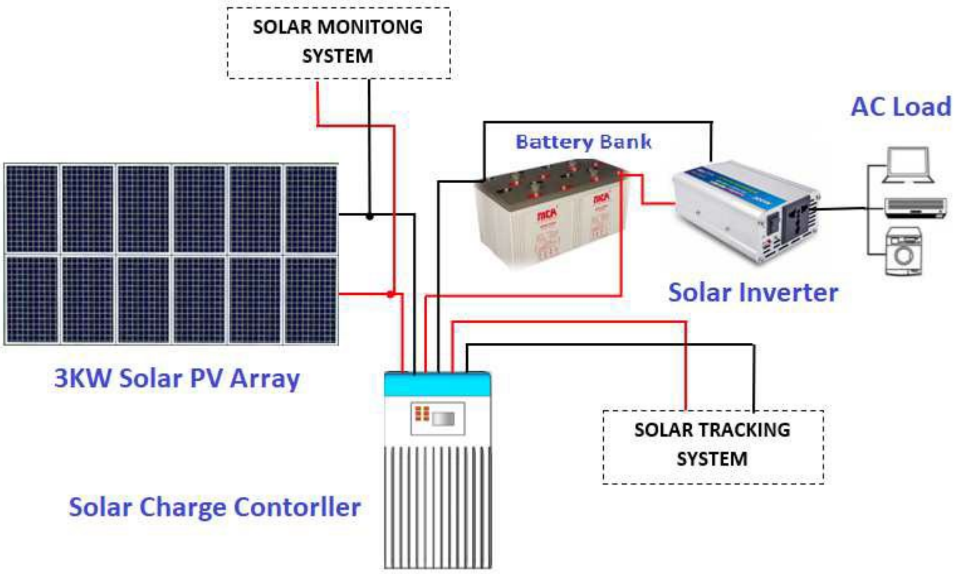


Figure 2.3 Diagram of the proposed monitoring and tracking system for the solar power system[24]

Building Integrated Photovoltaic (BIPV) Cells and Solar Thermal Panels are examples of monocrystalline and polycrystalline silicon[25]. New technologies are emerging at a breakneck rate. Solar cells are getting more efficient, transportable, and even bendable, making them easier to install. Aside from the materials used to boost the efficiency of solar cells, concentrators are gaining prominence. Since straight sunshine is by far the most common source of energy on Earth, solar concentrators have a huge chance of making a lot of alternative energy and helping to meet the world's energy needs in the future[26].

Solar power offers numerous environmental benefits, with its primary advantage lying in its eco-friendly nature. As a clean energy source, solar power does not emit greenhouse gases or other pollutants during its utilization, contributing significantly to a cleaner and healthier atmosphere[22]. Another key advantage is the attainment of energy independence through the installation of solar panels on residential or commercial structures. This empowers individuals and businesses to generate their electricity, providing greater control over energy production, reducing reliance on external sources, and potentially leading to cost savings. Additionally, solar energy brings forth a multitude of advantages, including enhanced operating strategies, system-friendly deployments, the latest advancements in renewable source distribution, updated power station programming, and investments in stable resources like demand-side resources, electric energy storage, grid architecture, and reliable production methods. This comprehensive array of benefits positions solar energy as a pivotal player in sustainable and self-sufficient energy solutions.

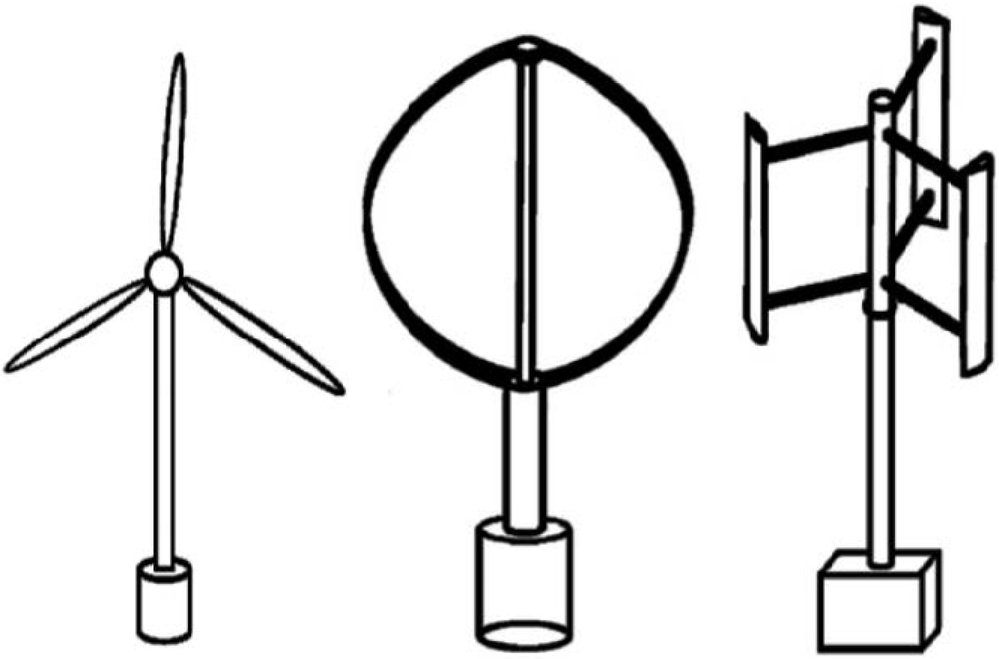
Despite its environmental benefits, solar energy comes with notable drawbacks. One significant disadvantage is its intermittent availability, reliant on sunlight and susceptible to weather conditions, making it less dependable during cloudy days, storms, and winter's shorter days. Another drawback is the high initial costs associated with obtaining and installing solar equipment, despite a gradual decline in expenses over time. This upfront financial investment may serve as a deterrent for individuals and businesses considering solar panel adoption. Lastly, there are substantial challenges related to energy storage, as the intermittent nature of solar energy necessitates storage systems for power supply during periods without sunlight. While battery technology is under development, it poses a potential additional cost to the overall solar energy system.

2.2.2 Wind Energy

Wind power generation has grown quickly in recent decades, owing to limited fossil fuel supply and environmental concerns over pollution. According to the Global Wind Energy Council (GWEC) estimate, 60 GW of new wind power systems were deployed in 2015[27]. Wind energy has long been vital in human history, and it is not a new technology. Since antiquity, humans have used technology to convert the kinetic energy of the wind into useful mechanical power. Wind energy was first utilized to power boats on the Nile River, which is the longest river in Africa and has historically been called the longest river in the world[28].

Wind energy, as a low-cost renewable energy source, is favored by all countries in the global energy transition due to its clean and environmental benefits[29]. In today's increasingly critical energy concerns, wind energy as a highly efficient renewable energy source has received extensive attention. Wind energy has an energy flow that is more varied and spread out than other green energy sources like solar or wave energy. Also, the area's wind profile and wind potential will be greatly affected by places with different surface qualities, such as land-sea, land-lake, land-river, and land-sea-lake-river connections, and by places with different roughness factors[30][31].

Vertical Axis Wind Turbines (VAWT) and Horizontal Axis Wind Turbines (HAWT) are two types of wind turbines that can turn wind energy into electricity. Figure 2.4 (a) is a picture of a standard HAWT, Figure 2.4 (b) is a picture of a Darrieus VAWT, and Figure 2.4 (c) is a picture of a Zephyr VAWT.



(a) HAWT (b) Darrieus VAWT (c) Zephyr VAWT

Figure 2.4 Various types of wind turbines[32]

Wind energy stands out as a clean and sustainable power source, harnessing the natural occurrence of wind that won't deplete over time. Operating without emitting greenhouse gases or air pollutants, wind energy plays a crucial role in combating climate change and air pollution, distinguishing itself from traditional fossil fuels[18]. Another set of advantages lies in the scalability and flexibility of wind energy. Whether implemented on a small scale or as large-scale utility projects, wind farms contribute to the development of a more reliable and robust energy system. Integration into existing electrical grids, along with collaboration with other renewable sources, enhances the adaptability of wind energy. Lastly, wind power emerges as an economically successful and dynamic green energy option, offering a constant supply of clean and cost-effective energy. Its benefits include increased installed capacity, improved safety, and an unlimited source of renewable power.

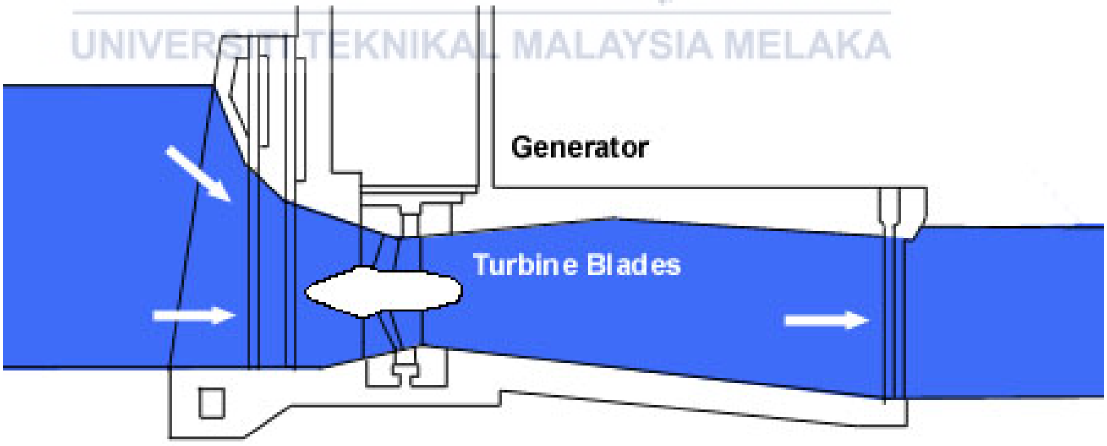
Despite its environmental advantages, wind energy faces notable drawbacks, with one significant disadvantage being the high upfront costs associated with building wind infrastructure. The substantial financial outlay required can impede widespread adoption, especially in economically constrained regions, hindering the transition to renewable energy. Another issue pertains to the noise generated by wind turbines. The mechanical noise from electricity-generating components and the airflow noise from rotating blades can be disruptive. This noise can have implications beyond the environmental realm, affecting activities such as fishing by making it challenging for hunters to catch fish, given their sensitivity to disturbances. These challenges underscore the need for continued technological advancements and mitigation strategies to make wind energy more accessible and socially acceptable.

2.2.3 Tidal Energy

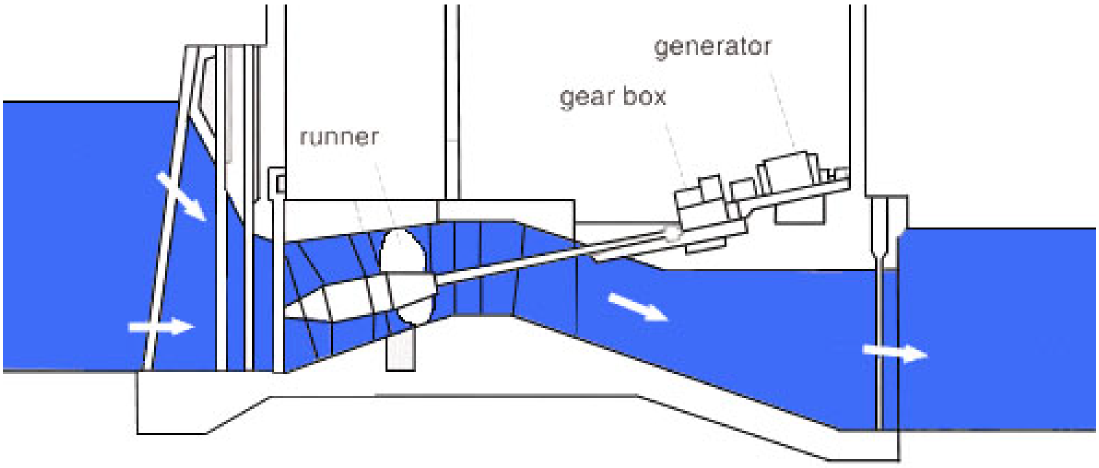
There are many ways to get green energy from the seas. The ocean takes up about 71% of the earth's surface and has a lot of energy in the form of waves and water currents. [33]. Potential energy is made when the seas receive solar radiation, which makes them move horizontally in ways that depend on how rocky the bottom is. The sun, moon, and earth all have a pull on the earth, which causes the sea level to rise and fall. The earth and moon are being pulled apart in two ways. The moon's pull-on Earth causes high tide, which pulls the ocean water facing the moon towards it. When the moon pulls the solid part of the earth away, a similar high tide happens on the other side of the earth, away from the moon.

Tidal energy is obtained from the hydropower system, which converts tide energy into electricity. Water flowing into and out of a bay can create electricity. Every day, there are two high tides and two low tides. Tidal power plants generate electricity every twelve hours, with no generation during the six-hour period in between. Therefore, if the seas in the world are not dry, tidal energy can produce electric energy.

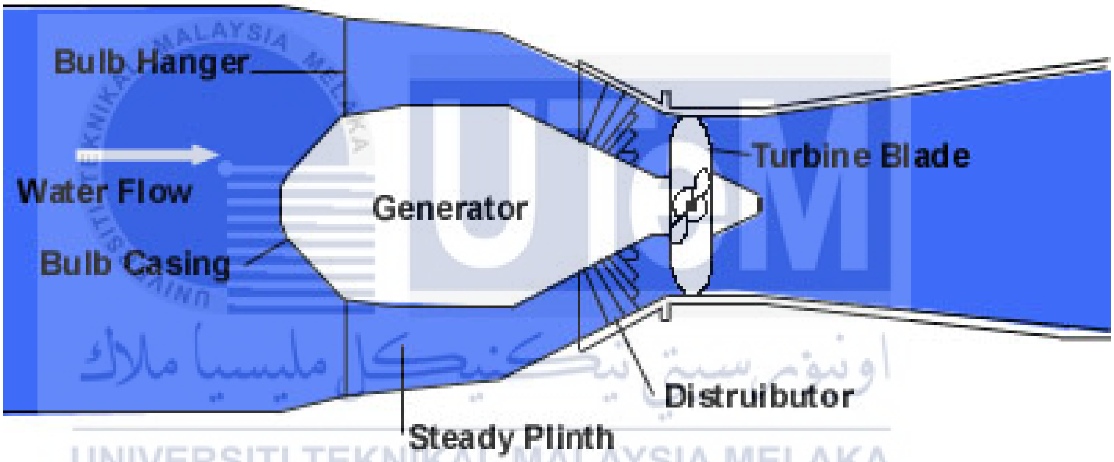
Bulb turbine, rim turbine, and tubular turbine are all types of hydroelectric turbines that are used to generate electricity from the movement of water. Three types of hydroelectric turbines are shown in Figure 2.5 (a) the bulb turbine, Figure 2.5 (b) the rim turbine, and Figure 2.5 (c) the tubular turbine. One kind of bulb turbine called a Kaplan turbine is intended to be built right inside a dam. The generator and turbine blades are housed inside a large bulb-shaped housing. The water flows through the blades and turns the generator to produce electricity. A rim turbine is a type of Pelton turbine that is designed for high head applications. It is made up of numerous buckets placed in a circle around a wheel. The buckets receive the water, which causes the wheel to spin and produce electricity. A tubular turbine is a type of Francis turbine that is designed for low head applications. The generator and turbine blades are contained in cylindrical housing. Electricity was produced when the water flows through the blades of generators.



(a) Bulb turbine



(b) Rim turbine



(c) Tubular turbine

Figure 2.5 Types of turbines are used for tidal energy[34]

Tidal energy boasts several significant advantages, beginning with its high energy density, allowing for the generation of substantial electricity with relatively modest infrastructure. Utilizing tidal turbines, large volumes of moving water can be efficiently converted into electrical energy, providing a concentrated and potent power source. Another key benefit is predictability, as tidal cycles can be accurately forecasted years in advance, offering a level of reliability unmatched by other intermittent renewable sources such as solar or wind energy. This predictability enables precise planning for energy production and grid integration. Lastly, tidal energy stands out for its environmental friendliness, producing electricity without burning fossil fuels or emitting greenhouse gases, thereby reducing carbon emissions, and mitigating climate change. With minimal contributions to air and water pollution, tidal energy exhibits a lower environmental impact compared to traditional energy sources like coal or natural gas.

Despite its merits, tidal energy confronts several drawbacks, foremost among them being the high cost of constructing tidal energy plants. The necessity for robust structures due to the denser nature of water compared to air results in the need for stronger installations than traditional wind turbines, with varying building expenses based on the technology employed. A second challenge is the susceptibility to corrosion and the need for consistent maintenance due to the corrosive effects of saltwater on machinery. Tidal energy systems, constructed with materials resistant to rust, still demand frequent upkeep, presenting logistical challenges, especially for submerged components. Lastly, the environmental impact on sea life is a concern, with tidal energy plants potentially harming birds, seals, and marine life through turbine blades and underwater noise. These ecological implications emphasize the importance of balancing the benefits of tidal energy with proactive environmental management.

2.2.4 Biomass Energy

The International Energy Agency says that the amount of energy used around the world will rise by 53% by 2023, with 70% of that increase coming from developing countries. With more people needing energy and less pollution, biomass is thought to be one of the most potential sustainable green energy sources that can help us use less fossil fuels. Biomass energy is the energy that comes from things like plants, farm waste, forest waste, and even some kinds of animal waste[35].

Biomass can be converted into many different types of energy (heat, electricity, and transportation fuels); however, conversion procedures vary depending on the type of energy to be obtained. Biomass energy can be obtained through several processes, including direct combustion, gasification, pyrolysis, and liquefaction[36]. An example of gasification processes is shown in Figure 2.6. The thermochemical process of gasification changes solid fuel into gaseous fuel. The main goal of the gasification process is to turn solid fuel into as much liquid fuel as possible.

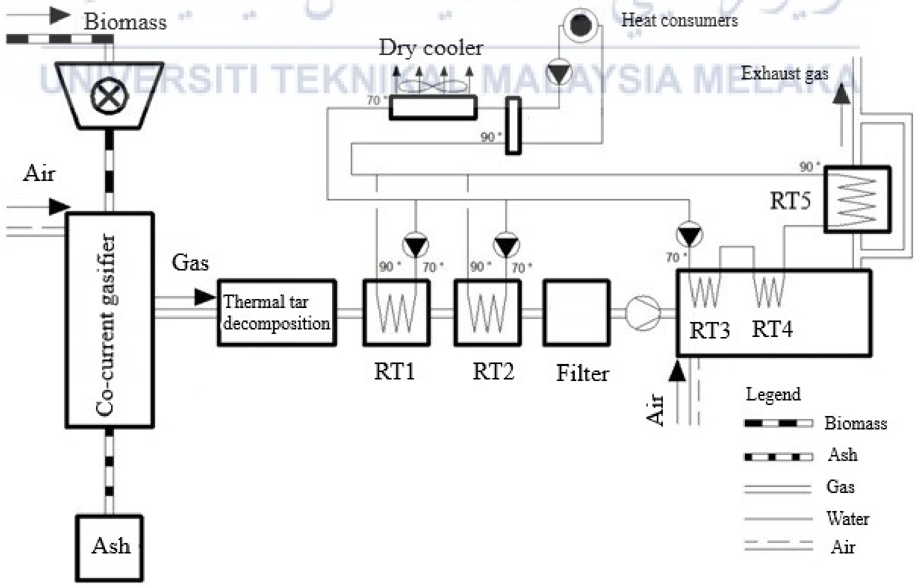


Figure 2.6 Principal scheme of a CHP plant using gaseous fuel obtained in gasification of biomass[37]

Biomass energy presents several key advantages, starting with its ability to effectively utilize waste materials that would otherwise contribute to environmental issues. By harnessing biomass energy, waste products, including forestry residues, agricultural by-products, and organic municipal waste, can be repurposed instead of ending up in landfills or emitting methane. Additionally, biomass energy contributes to the reduction of greenhouse gas emissions, as the carbon dioxide released during biomass combustion is part of the natural carbon cycle. Unlike fossil fuels, biomass does not introduce new carbon into the environment, as the plants used in its production absorb carbon dioxide while growing. These characteristic positions biomass energy as a potential mitigator of net greenhouse gas emissions when compared to traditional fossil fuels. Furthermore, biomass is a renewable and sustainable energy source, as it is derived from organic materials such as wood, crop residues, and energy crops, which can be regenerated through environmentally friendly practices, reinforcing its status as a reliable renewable energy option.

While biomass energy offers environmental benefits, it comes with notable disadvantages. One primary concern is the limited land utilization and supplies as biomass relies on organic materials such as wood, crop by-products, and agricultural waste. Meeting widespread energy demands may require extensive land use, potentially impacting natural ecosystems or competing with food production. Another significant drawback is air pollution associated with biomass combustion, producing particulate matter, nitrogen oxides, Sulphur dioxide, and volatile organic compounds. Inadequate emission controls in biomass facilities can adversely affect air quality and human health. Additionally, biomass energy's dependence on weather and seasonal variations poses challenges, with the availability of biomass influenced by changes in seasons and weather conditions. Factors like droughts can impact crop yields and biomass feedstock development, affecting the reliability and consistency of biomass energy generation. These concerns highlight the need for careful consideration and mitigation strategies when implementing biomass energy solutions.

2.2.5 Hydropower Energy

Hydropower is a type of clean energy that uses the force of falling or moving water to make electricity. Most hydropower plants have a dam or some other construction that holds water back in a reservoir. In short, the force of falling or moving water makes the blades of a turbine spin, which moves a generator to make electricity[38]. In Figure 2.7, a standard power plant is shown. A dam was used to hold a lot of water and make a big lake-like pond. Control gates at the bottom were used to flow the water from the reservoir into a penstock which is a large pipe or tunnel. When water hits the blades of a turbine and makes it spin, and the turbine is hooked up to a generator, electricity is made. As the turbine spins, it rotates the generator's rotor, which is made up of electromagnets. So, the rotation of the rotor within a stationary set of coils generates an electromagnetic field, which causes electricity to be generated. The generator's output is sent to a transformer, which raises the voltage for efficient transmission across long distances via power lines. The high-voltage power is then sent to local distribution lines, where transformers reduce the voltage to levels acceptable for use in homes, companies, and industries. Using overflow, the water that goes past the pumps is then sent down the river.

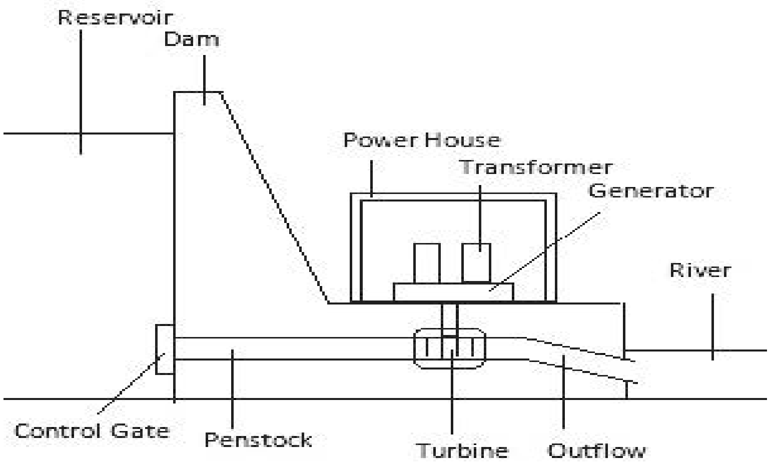


Figure 2.7 Conventional hydropower plant[39]

Hydropower also related with pumped storage hydropower (PSH) is a grid-connected energy storage technology[40]. PSH systems are typically made up of two reservoirs at different elevations that are linked by a tunnel or pipeline. When there isn't much need for energy, extra electricity is used to pump water from the lower tank to the top reservoir. When there is a big need for energy, water from the higher pool is sent through a propeller to make energy. When a hydropower plant has numerous producing units running in parallel, the shared-penstock approach is employed in the main penstock, which is a popular practice to save construction costs as shown in Figure 2.8.

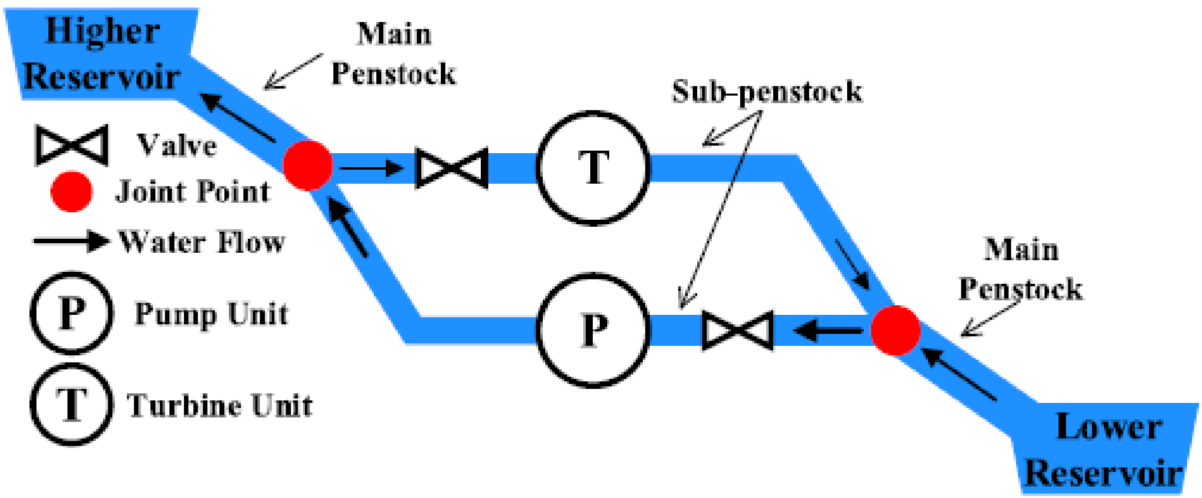


Figure 2.8 Water flow in hydraulic short-circuit mode[41]

Hydropower, a natural and sustainable energy source, offers several advantages. Functioning based on the continuous natural flow of water, hydropower stands as a renewable energy option, generating electricity reliably as long as water is available. Beyond electricity production, hydropower projects often involve the construction of dams and reservoirs, providing additional benefits such as water storage for irrigation, flood control, and water supply management. These structures contribute to regulating downstream water flow, ensuring a consistent supply even during dry seasons. Furthermore, hydropower projects create opportunities for water recreation and tourism, with reservoirs serving as venues for activities like boating, fishing, and water sports. This not only attracts tourists but also bolsters the local economy, enhancing the overall quality of life in the surrounding areas.

Despite its benefits, hydropower is not without drawbacks, with a significant environmental impact being a primary concern. The construction of hydropower dams often entails the flooding of large land areas, leading to the displacement of people, wildlife, and the loss of crucial habitats, ultimately causing the destruction of ecosystems, particularly in river valleys and downstream regions. Additionally, the alteration of natural water flows can disrupt fish migration and breeding patterns. Hydropower's impact extends to the disruption of river systems, as the construction of dams and reservoirs alters the natural flow of water and sediment downstream, negatively affecting river ecology, fish populations, and nutrient distribution. Furthermore, the risk of dam failure poses a serious threat, with potential catastrophic consequences arising from natural disasters, engineering flaws, or inadequate maintenance. Dam failures can result in significant loss of life, property damage, and environmental devastation downstream. These environmental concerns underscore the need for careful planning and management in hydropower projects to minimize adverse effects.

2.3 Microcontroller

A microcontroller is a single-chip computer system that is designed to execute specific tasks and control electronic devices[42]. A microcontroller has all of its processing, memory, and input/output parts on a single chip. Microcontrollers are frequently utilized in embedded systems, which are computer systems created to carry out specific tasks inside larger devices or systems. Consumer electronics, industrial automation, automobile systems, medical devices, and many more goods and applications use them. There are many kinds of microcontrollers on the market, and each one has its own features and functions. IoT applications frequently use microcontrollers like the Arduino, Raspberry Pi, and ESP8266. Because of their tiny size, low cost, and low energy consumption, microcontrollers are perfect for use in Internet of Things (IoT) devices. Microcontrollers are appropriate for many IoT applications since they can be configured to do a wide variety of functions. As they consume less energy, they are also fantastic for battery-powered devices.

2.3.1 ESP32

The ESP32 in an improved model of the ESP8266 with dual-core computing, more GPIO pins, built-in Bluetooth, Wi-Fi capabilities, a quick processor, and low power consumption[43]. It has built-in Wi-Fi and Bluetooth that work with both Classic Bluetooth and Bluetooth Low Energy (BLE). The Wi-Fi supports the 802.11 b/g/n standards and has several security features. It is frequently utilized for more intricate IoT applications that call for additional processing power or a variety of wireless protocols. Figure 2.9 shows an example ESP32.

Figure 2.9 ESP32 with the camera module[44]

The ESP32, with its dual-core Tensilica Xtensa LX6 processor, stands out in the realm of microcontrollers by enabling efficient multitasking and enhanced performance, a notable advantage over single-core counterparts. This capability proves particularly valuable for applications demanding simultaneous handling of multiple tasks. Additionally, the ESP32 integrates both Wi-Fi and Bluetooth connectivity, simplifying connections to local networks, the internet, and other devices, making it a suitable choice for Internet of Things (IoT) projects and wireless communication applications. Furthermore, the ESP32 is designed with power efficiency in mind, offering various sleep modes and power management features that make it well-suited for battery-powered or low-power applications, allowing users to conserve energy and extend battery life effectively.

The ESP32 has significant disadvantages despite all its benefits. It is noteworthy that it tends to consume a lot of power, especially when Bluetooth or Wi-Fi connections are active. This presents a problem for portable apps because it can quickly drain batteries. ESP32 boards or modules may not always be available, which could affect market accessibility even with its extensive use. The ESP32 is normally less expensive than similar microcontrollers, but on occasion it can cost more, which could be an issue for applications with limited funding. A 12-bit analogue to digital converter (ADC) resolution and very less RAM in comparison to some other microcontrollers are two more of the ESP32's drawbacks. Tasks needing more accuracy or involving intricate programming with large data buffers can find this problematic. Even with these drawbacks, the ESP32 is still a widely used option, and making the most of its application-specific use requires careful evaluation of these considerations.

2.3.2 Arduino

An open-source electronics platform called Arduino is made up both software and hardware elements[45]. By mixing sensors, actuators, and other electrical components with programmable microcontrollers, it offers a quick and adaptable method for developing interactive projects and prototypes. The Arduino board, which is the hardware component, often has an Atmel AVR or ARM microprocessor, as well as input/output pins and different connectors. There are numerous varieties of Arduino boards available, each with their own features and characteristics, including the Arduino Uno, Arduino Mega, Arduino Nano, and more. Both novice and seasoned manufacturers like Arduino because of its ease of use and extensive community support. It offers an easy and economical approach to learn about electronics, programming, and physical computing. Figure 2.10 shows the structure of the Arduino Uno board and its 14 pins.

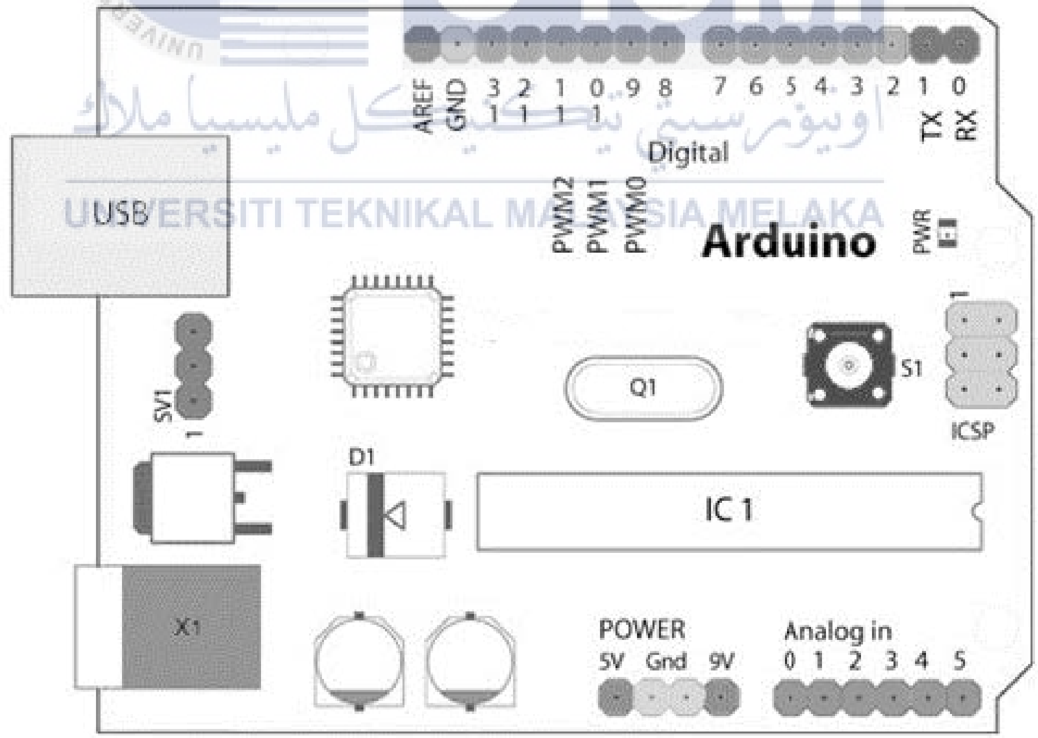


Figure 2.10 Layout and Pin Out of the Arduino Uno Board [46]

Arduino, renowned for its user-friendly features, stands out as an easily accessible platform with a straightforward programming language and development environment, tailored for beginners. The boards are designed with simplicity in mind, offering an easy learning curve that allows individuals with limited prior knowledge of electronics or programming to engage with it seamlessly. Additionally, Arduino serves as an excellent educational tool widely employed by institutions to teach robotics, programming, and electronics. Its simplicity and rapid practical results make it an ideal choice for introducing students to the realms of coding and electronics. Moreover, Arduino boards are cost-effective when compared to other microcontroller platforms, rendering them a practical and budget-friendly option for prototypes and do-it-yourself projects. The affordability of components and Arduino's open-source design further contributes to keeping project expenses down, making it an attractive choice for a wide range of applications.

Despite its popularity, Arduino does have notable disadvantages. One prominent drawback is its limited networking capabilities, even with the existence of features like Ethernet or Wi-Fi shields. While functional, these capabilities are not as robust or flexible as those found in specialized networking hardware, potentially complicating the connection to current internet protocols or the development of sophisticated networked applications. Additionally, due to their relatively low processing power, memory, and input/output pins, Arduino boards are not recommended for use in professional, industrial, or large-scale projects. Instead, they find their primary application in small to medium-sized project prototyping and educational contexts. The limited capabilities, such as CPU speed, memory size, and I/O proficiency, may prove insufficient for the demands of complex industrial systems or significant corporate endeavors. Furthermore, the lack of multitasking, as

Arduino employs a single-threaded programming approach, poses a significant drawback for projects requiring simultaneous execution of multiple tasks or real-time responsiveness. Despite these limitations, Arduino remains a versatile and widely used platform, but careful consideration of its constraints is essential for certain applications.

2.3.3 Raspberry Pi

The Raspberry Pi Foundation made the Raspberry Pi, which is a small single-board computer. It was made to improve basic computer science teaching and to give people a tool for testing and prototyping that didn't cost too much. There are several versions of the Raspberry Pi boards, which are about the size of a credit card. Each has its own features and specs. Here are some important features that most Raspberry Pi models have: It has a System on a Chip (SoC), GPIO (General Purpose Input/Output), an operating system, connection, video output, USB ports, storage, and extension. The Raspberry Pi is becoming better known because it is easy to use, can be changed, and has a lot of community support. It has been used in a variety of projects, such as home automation, robotics, movie centers, game emulation, Internet of Things devices, and teaching projects. In Figure 2.11, it can see the Raspberry Pi 3 Model B.

Figure 2.11 Raspberry Pi 3 Model B[47]

Raspberry Pi has a few advantages that contribute to its broad popularity. One major advantage of Raspberry Pi boards is their affordability, which makes them far less expensive than conventional computers. Due to its affordability, a wide spectrum of users—including professionals, students, and amateurs with tight budgets—can now utilize it. One other benefit is that Raspberry Pi boards are quite small—they can fit into a credit card—which makes them very portable and perfect for use in robotics, embedded systems, and other portable projects. In addition, because of its small size, low power consumption, and flexible networking options, Raspberry Pi is a great choice for Internet of Things (IoT) applications. Its appeal to people interested in cutting edge technology and innovation is increased by its capacity to act as a central hub for managing and monitoring devices in automated systems, smart homes, and other IoT efforts.

While Raspberry Pi offers affordability and portability, it comes with certain limitations. One notable drawback is its limited processing power, as the ARM-based processors on Raspberry Pi boards provide modest performance compared to desktop or laptop computers. This limitation can be a hindrance for tasks demanding substantial computational power, such as complex simulations or intensive data processing. Another disadvantage is the limited storage options, as most Raspberry Pi models rely on microSD cards, which may be slower and less durable compared to solid-state drives (SSDs) or hard disk drives (HDDs). This can impact applications requiring fast and reliable storage access, such as large-scale databases or high-speed data logging. Additionally, Raspberry Pi's restricted power output over USB ports poses challenges for high-powered USB devices, potentially necessitating additional power sources or a powered USB hub for devices like external hard drives or power-hungry gadgets. Despite these limitations, Raspberry Pi remains a versatile and widely used platform, with careful consideration needed for applications requiring more computational power or storage capabilities.

2.4 Water Quality Monitoring

Monitoring water quality entails evaluating a few characteristics to ascertain the state and suitability of water for various uses. There are a several crucial characteristics that are frequently considered in water quality monitoring, even if the precise parameters monitored may vary based on the application and regulatory requirements. These variables give information about the biological, chemical, and physical properties of the water, enabling an evaluation of its general quality. Some of the most important factors are temperature, pH, Dissolved Oxygen (DO), turbidity, Electrical Conductivity (EC), Total Dissolved Solids (TDS), nutrients, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), heavy metals, microbiological, pesticides, and herbicides. These parameters are not all inclusive, and depending on the water source, the intended usage, and local laws, more parameters may be pertinent. To give a thorough evaluation of water quality and pinpoint any possible problems or causes of contamination, water quality monitoring programmers frequently consider a mix of these factors. In Figure 2.12, an example of the design of a water quality monitoring system with IoT is shown, and Figure 2.13 shows the block diagram of this project.

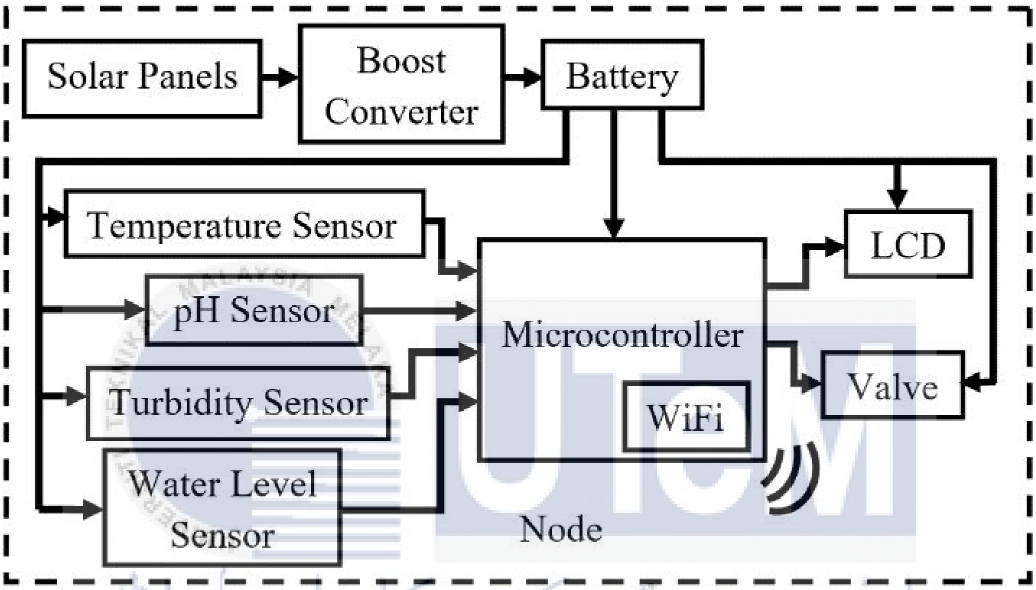


Figure 2.12 Design of Water Quality Monitoring System with IoT[48]

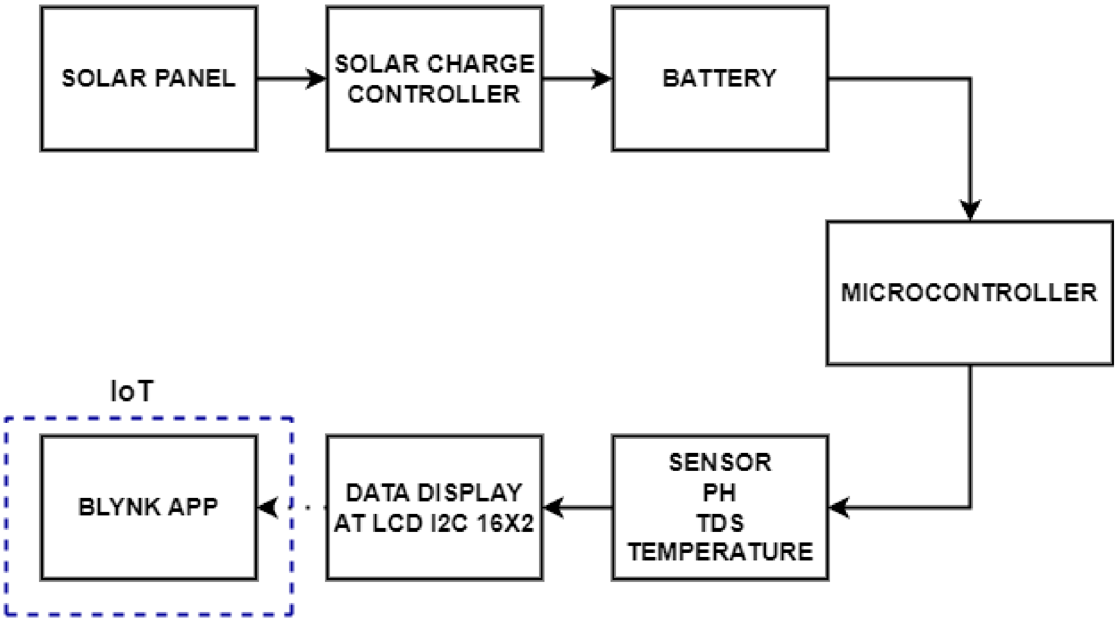


Figure 2.13 Block diagram of project

2.4.1 The pH of Water

Pure water is thought to have a pH of 7, which is considered neutral. The pH scale shows how many hydrogen ions (H+) are in a solution of water[49]. A pH of 7 or above denotes alkalinity or basicity, while a pH below suggests acidity. It's crucial to remember that the pH of water can change depending on elements like temperature, gases in the atmosphere, and dissolved chemicals. It has a considerable impact on the chemical and biological processes that take place in water, which can have a negative effect on the environment, human health, and industrial activities. To guarantee the safety of aquatic life, human health, and the environment, pH of water sources must be monitored and managed. It enables the identification and resolution of potential pollution, contaminant, and water suitable problems.

By calculating the pH value of a solution, pH sensors are instruments that are used to measure a solution's acidity or alkalinity. Numerous industries utilize pH sensors, including those that monitor the environment, purify water, produce food and beverages, study chemistry, and monitor life. Although there are many various kinds of pH sensors, the glass electrode pH sensors are one of the most used. A thin glass membrane that is responsive to hydrogen ions makes up the glass electrode. A reference electrode is located inside the electrode and is submerged in a potassium chloride (KCI) solution, which is a solution with a constant pH. Additionally, elements including temperature, electrode ageing, pollution, and chemical interference might have an impact on pH sensors. To keep the sensors in good working order and ensure accurate measurements, regular maintenance and careful storage are required.

PH sensors play a pivotal role in diverse sectors and applications, offering a multitude of advantages that contribute to their indispensability. Their precision in providing accurate readings of solution acidity or alkalinity enables real-time data processing and swift responses to pH level changes[50]. The broad measuring range of pH sensors allows their application in various conditions, from strongly acidic to highly alkaline solutions. Notably, their non-destructive nature ensures sample integrity, making them particularly valuable in fields like food and pharmaceutical manufacturing. Furthermore, the cost-effectiveness of pH sensors, coupled with their accessibility in various sizes and types, makes them a preferred choice over other testing methods. In essence, the accuracy, wide measurement range, non-destructive properties, integration with automation systems, and affordability collectively position pH sensors as indispensable tools for pH measurement and control across diverse industries.

In conclusion, while pH sensors are widely utilized for their ability to measure solution acidity or alkalinity, they are not without significant drawbacks. The sensitivity of their electrodes poses a challenge, with measurement errors arising from factors like temperature variations, electrical interference, and chemical impurities affecting electrode performance. Frequent calibration is necessary to maintain accuracy, and over time, the sensitivity and reaction time of electrodes may decline, requiring maintenance, replacement, and periodic calibration for reliable functioning. Additionally, the relatively high cost of pH sensors, coupled with ongoing expenses for maintenance, calibration solutions, and electrode replacement, should be carefully considered. Despite these challenges, technological advancements have made strides in mitigating some of these issues, and the susceptibility to these problems may vary among different types of pH sensors. Overall, while recognizing their drawbacks, ongoing innovations continue to enhance the performance and applicability of pH sensors in various industries.

2.4.2 The Turbidity of Water

Turbidity is the term used to describe the cloudiness or haziness that a liquid exhibit when suspended particles, such as sediment, silt, or organic matter, are present[51]. It is a standard tool for gauging liquid clarity in environmental and water quality monitoring. Turbidity is commonly measured with a turbidimeter or a nephelometer, which quantifies the quantity of light scattered by the particles in the liquid. Nephelometric turbidity units (NTU) or Formazin turbidity units (FTU) are commonly used to express the value obtained from the instrument, which measures the intensity of light passing through the liquid. Turbidity levels are frequently regulated by environmental agencies and organizations to protect water quality, with precise limitations set based on the intended use of the water. Monitoring turbidity aids in locating probable sources of pollution, analyzing trends in water quality, and evaluating the efficiency of water treatment methods.

Turbidity sensors play a crucial role in assessing water quality by providing rapid and precise measurements of suspended particles or solids, determining the turbidity or clarity of water. Widely employed in environmental monitoring, these sensors help analyze changes in water quality and detect pollution events such as sediment runoff or algae blooms. In the realm of drinking water treatment, turbidity sensors are vital for monitoring filtration system effectiveness, ensuring water treatment meets required standards. Additionally, they contribute to optimizing and controlling industrial processes, facilitating adjustments to maintain consistent output quality. Beyond practical applications, turbidity sensors are valuable for research and scientific studies, offering insights into sediment transport, erosion processes, and the impact of contaminants on aquatic ecosystems. In summary, turbidity sensors provide a reliable and efficient means of quantifying suspended particles, benefiting water quality assessment, environmental monitoring, and scientific research.

Turbidity sensors, while widely used for water quality assessment, face certain limitations. Sensitivity to air bubbles in the tested fluid can lead to inaccurate readings, and precise calibration using accepted reference solutions is crucial to ensure accurate results. Constraints in detecting very small or large particles may limit their suitability for applications requiring measurements outside their intended range. Impact from color, organic particles, and environmental factors like temperature and pH necessitate additional filtration or sample preparation, potentially affecting findings. Routine maintenance and cleaning are essential to prevent erroneous data caused by particles or contaminants on the sensor surface. Despite these challenges, the high cost of turbidity sensors for budget-constrained applications, manufacturers are actively working to improve designs and overcome limitations, highlighting ongoing efforts to enhance their performance.

2.4.3 Temperature of Water

Water's temperature can change depending on its source, location, and external forces. There are some common temperature ranges for water: freezing, cold water, room temperature, warm water, hot water, and boiling. Understanding and monitoring water temperature is critical for managing ecosystems, safeguarding aquatic life, forecasting weather patterns, ensuring human health and safety, and reducing the effects of climate change[52].

To detect the temperature of water, a variety of sensors can be used. The intended temperature range, accuracy requirements, application, and budget all play a role in the sensor selection. Several popular kinds of sensors used to gauge the temperature of water include thermocouples, resistance temperature detectors (RTDs), thermistors, infrared (IR) temperature sensors, and integrated circuits (IC). When choosing a temperature sensor for water, consider aspects such as the intended temperature range, accuracy requirements, response time, climatic conditions, and compatibility with the measuring system or controller.

Temperature water sensors offer significant advantages, foremost among them being their ability to provide reliable and accurate water temperature measurements. This precision is particularly crucial for applications requiring exact temperature control, such as in industrial processes or scientific research. Additionally, these sensors contribute to safety by detecting overheating or extremely high temperatures in water systems, triggering alarms or system shutdowns to prevent damage or potential hazards. This enhances workplace safety and protects equipment and individuals. Furthermore, temperature water sensors play a vital role in research and development activities, enabling precise temperature control, data collection, and analysis. This support extends to various fields, including chemistry, biology, and materials science, allowing researchers to conduct experiments with accurate temperature control and ensuring the reliability and reproducibility of results.

Despite their advantages, temperature water sensors come with notable disadvantages. One significant drawback is their limited accuracy and precision, influenced by factors such as sensor placement, calibration, and environmental conditions. In areas requiring precise temperature control, these inaccuracies can pose challenges. Another concern is the potential for sensor malfunction or failure over time, as electronic devices are susceptible to technical issues that can lead to unreliable temperature measurements. Additionally, the need for calibration and maintenance further adds to the overall cost and effort associated with using temperature water sensors, requiring periodic recalibration or replacement to ensure accuracy and longevity.

2.5 Comparison of water quality monitoring based on previous research

In summary, water quality monitoring is the process of regularly testing and analyzing water samples to ensure that the water meets specific quality standards and is safe for human consumption and use. The monitoring process involves collecting samples from various sources, such as rivers, lakes, wells, and public water systems, and testing the water for physical, chemical, and biological contaminants that may be harmful to human and environmental health. To test the water, some parameters were used, like a temperature sensor, a pH sensor, a turbidity sensor, a dissolved oxygen sensor, and a water level sensor. Every parameter mentioned has advantages and disadvantages. So, before using the parameter, make sure it is in good condition and use it in accordance with its function. Table 2.1 below shows the comparison of water quality monitoring in some fields.

Table 2.1 Comparison of Water Quality Monitoring

FIELD	SENSOR	SOLAR USING
FISH FARMING[53]	• TEMPERATURE • TURBIDITY • pH	YES
BIOLOGY[54]	• pH • TURBIDITY • WATER LEVEL • TEMPERATURE • DISSOLLVED OXYGEN	NO
CHEMICAL[55]	• TEMPERATURE • pH • TDS • CONDUCTIVITY • TURBIDITY	NO
FRESHWATER BIODIVERSITY[56]	• CONDUCTIVITY • TDS • pH • TEMPERATURE • DISSOLVED OXYGEN	NO
NATURAL WATER BODIES[57]	• TEMPERATURE • DISSOLVED OXYGEN • pH • TURBIDITY • AMMONIA	YES

The paper "Quality Maintenance of Fish Farms: Development of a Real-Time Water Quality Monitoring System" was written by Billah et al, 2019 is about making a real-time method for checking water quality in fish farms, focusing on keeping the water conditions right for catfish habitat [52]. This paper talks about how fish farmers have trouble keeping their fish healthy because of issues with the water where the fish live. Someone must check the water for the farmers, which costs a lot of time and money. This paper discusses making a system to monitor the water and quickly tell the farmers what is happening. Info about the water quality would be sent to the farmer's water quality on the Internet of Things (IoT).

Farmer can better take care of their fish this way. The paper says this is very important to keep the fish alive and ensure they are safe to eat. Sensors, a small computer, and the Internet of Things were used to build the system, which checks things like the temperature and oxygen level of the water. The tests went well, and the paper says that this method can help farmers take better care of their fish and the water where they live. It would be good to discuss how easy it is to use and how well it will work in real life. Overall, the paper shows how they made a system that can always check the water quality at fish farms. This paper is significant for the fish's health and ensuring food safety.

The paper “Development of IoT Monitoring system for Aquaculture Application” was written by Hawari et al, 2022[58]. The authors underscore the economic significance of aquaculture in Malaysia and the growing need for freshwater production. They draw attention to the shortcomings of conventional methods for assessing water quality. They emphasise the importance of ongoing, thorough surveillance to improve efficiency and decrease expenses. The study suggests a solution to the effects of climate change on water quality by proposing an Internet of Things (IoT) system. This system incorporates sensors, microcontrollers, an Orange Pi, a database, web services, and mobile/desktop applications to monitor parameters such as pH, temperature, and turbidity. The system's accuracy and precision undergo rigorous testing and calibration, establishing it as a significant tool for fish farmers to effectively address water quality concerns and enhance efficiency in aquaculture production.

2.6 Water quality system with IoT for fish farming

Fish farming or aquacultural also known as the practice of raising fish and other aquatic organisms in confined spaces like tanks, ponds, or enclosures[59]. To meet the rising demand for seafood and ease pressure on wild fish populations, it is crucial to increase fish production. There are several types of fish farming which are freshwater farming, marine farming, and brackish water farming. Each type involves different species and farming methods. Fish can be farmed in various systems such as ponds, raceways, cages, and recirculating aquaculture systems (RAS). Figure 2.14 shows an example of a cage that was used in aquaculture. Each system has its own advantages and suitability for specific species. Various fish species can be raised, depending on the farming system and geographical location. Salmon, tilapia, trout, catfish, carp, and prawns are a few of the fish that are frequently farmed.

Figure 2.14 Cage for Aquaculture[60]

The practice of cultivating fish in an enclosed body of water known as “fish farming in a pond” is often considered to be the most successful type of fish farming. Figure 2.15

shows the fish farming in a pond and fish farming in a ground pond. To ensure the success of fish farming, it is important to select an area that has an adequate quantity of water and enough drainage. Build the pond to the correct depth, and then maintain it by keeping an eye on the temperature, the oxygen content, and the quality of the water overall. Choose fish species that can thrive in the conditions of the region and satisfy the needs of customers. The pond should be stocked with fry or fingerlings, and appropriate food should be provided for the fish. Put disease control producers into effect and maintain consistent health checks on the fish. When the time is appropriate, harvest the fish, and then devise a strategy for marketing and selling the fish. To run a business that is both sustainable and responsible, farmers must be professionals. This step is also used for fish farming in cages and raceways.

Figure 2.15 Fish farming in a pond and fish farming in a ground pond[61]

Fish on farms are often fed specially formulated feed that is made to give them the nutrients they need to flourish. Depending on the fish's growth stage and the species being farmed, the feed mix changes. Sustainable fish farming techniques attempt to minimize their negative effects on the environment, lessen their reliance on wild fish for food, and protect the wellbeing of the farmed fish. The promotion of ethical farming methods is aided by certifications like those offered by the Aquaculture Stewardship Council (ASC) and Best Aquaculture Practise (BAP).

Fish farms are susceptible to disease outbreaks, which can result in large financial losses. To reduce the danger of contracting a disease, preventive measures, including yearly physicals, vaccinations, and biosecurity procedures, are crucial. One of the causes of disease comes from water. The device is very environmentally friendly because it uses solar and IoT to make work easier.

A method for monitoring the water quality in fish farms that is based on IoT can help farmers keep the water in their farms in the best condition for their fish. This will lead to healthier fish and higher yields. Sensors that measure things like temperature, pH, and liquid oxygen are usually a part of the system. The sensor sends the data to a cloud-based platform, where the farmer can examine and keep an eye on it from a distance. Based on the study on tracking systems for water quality in fish farms, keeping the water quality high is important for the health and growth of farmed fish[62].

Aquaculture, sometimes known as fish farming, has various advantages, including reducing pressure on wild fish supplies by producing huge amounts of fish for human use in a consistent and efficient manner. It provides a controlled environment where water quality, temperature, and nutrition can be adjusted, resulting in healthier fish that are less prone to parasites and illnesses. By limiting bycatch and eschewing destructive fishing techniques, the industry promotes economic development, especially in rural and coastal communities, and supports employment creation while aiding in marine conservation. Fish farming also promotes resource efficiency by using less land, energy, and water. Selective breeding improves genetic features, while quality control techniques raise the uniformity and caliber of fish products. In addition, the industry drives innovation, and technological breakthroughs, particularly in automation and water recirculation systems. However, responsible management practices are crucial to mitigate negative environmental impacts and ensure long-term sustainability.

Fish farms represent major environmental dangers, contributing to water contamination, oxygen loss, and aquatic ecosystem damage due to fish waste. Diseases and parasites can have a detrimental effect on wild fish populations in heavily populated fish farms. Escapes from these establishments could result in a decrease in the genetic diversity of wild fish and genetic smuggling. Furthermore, because fish farms depend on wild fish for feed, overfishing happens, which could be harmful to the environment. Other concerns include antibiotic resistance, social and economic challenges, chemical use, pollution, and climate-related issues involved with fish farming.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Aquaculture is vital to addressing the rising global demand for fish. However, fish health and growth depend on consistent high-water quality. The health of fish populations depends on careful monitoring of water quality indicators such temperature, dissolved oxygen (DO) levels, pH, and turbidity. Manual monitoring takes a lot of effort and time and can make mistakes. Therefore, the use of solar-powered sensors integrated with IoT (Internet of Things) technology provides a robust and dependable method for monitoring water quality in fish farms in real time.

3.2 Selecting and Evaluating Tools for a Sustainable Development

The Sustainable Development Goals (SDGs) are a set of 17 world goals created by the United Nations in 2015. By the year 2030, they hope to have eliminated poverty, protected the environment, and ensured universal prosperity and peace. Poverty eradication, gender equality, education, healthcare, economic growth, climate change, and justice are just a few of the many interwoven topics addressed by the SDGs. To solve global concerns and build a more sustainable and equitable world, the SGDs serve as a framework for cooperation across government, organizations, corporation, and individuals. Figure 3.1 below shows the picture of a sustainable development goal.

Figure 3.1 The Global Goals for Sustainable Development

In line with SDG 7, a solar water quality monitoring system with IoT for fish farming can reduce the environmental impact. This project used solar panels to convert sunlight into usable electricity. Besides, the optimal use of solar power helps lower the overall cost of raising fish, and this project is well suited for off-grid fish farming as it can function even in places with little or no access to electrical grids. As a fish farm expands, farmers can make this system larger. Finally, solar panels can survive for many years with very little upkeep, so farmers can save more money.

The solar water quality monitoring system with IoT for fish farming also supports SDG 14: "Life Below Water" which is fisheries and aquaculture provide ample opportunities to reduce hunger and improve nutrition, alleviate poverty, generate economic development, and improve natural resource utilization. Renewable solar energy is used to power internet of Things devices that track key water parameters for fish health around the clock. Through real-time monitoring, data analysis, and decision assistance, the system encourages sustainable aquaculture practices by helping fish farmers maximize conditions while decreasing resource consumption and safeguarding aquatic ecosystems. This initiative helps achieve SDG 14's objective of protecting life below water by making use of solar energy and encouraging sustainable fish farming practices. Figure 3.2 below shows the block diagram of the project with SDG 7.

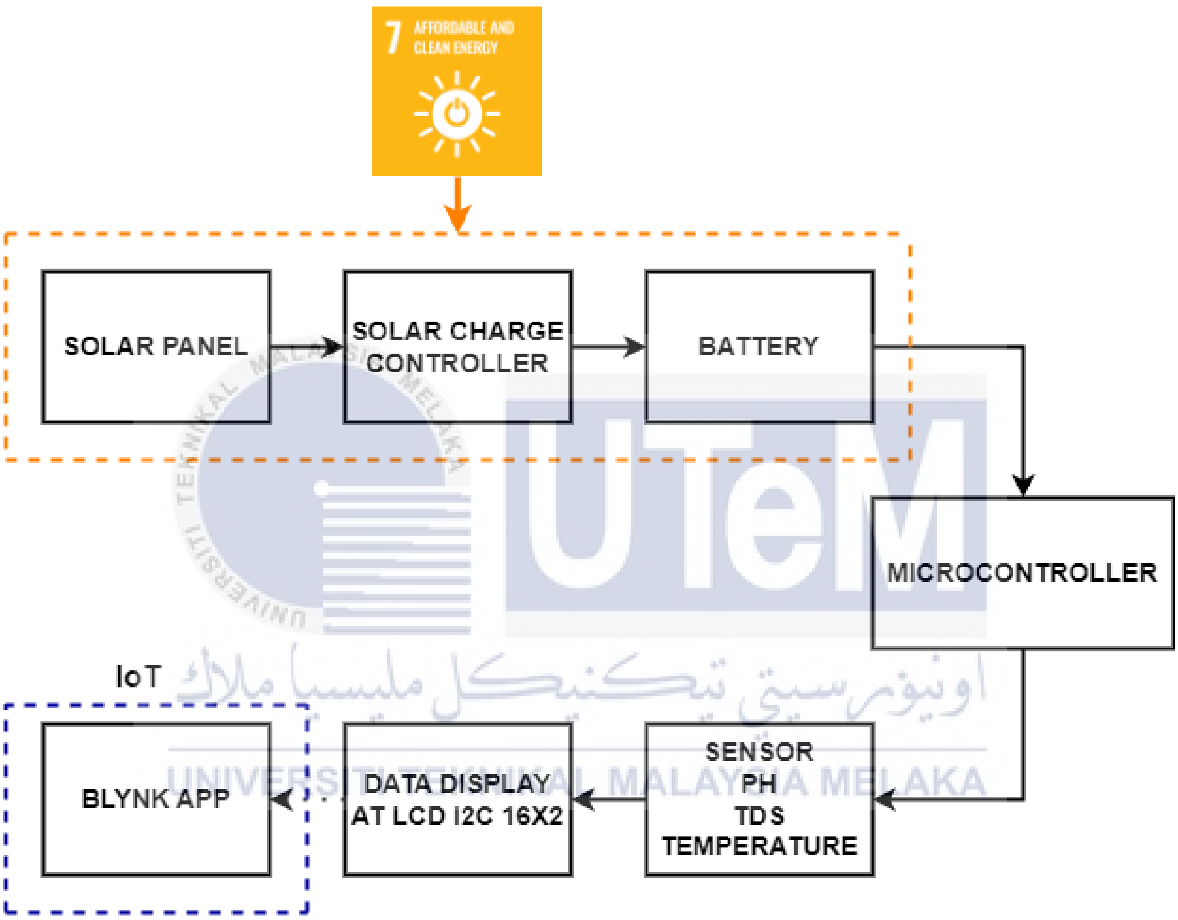


Figure 3.2 The SDG 7 in the block diagram project

3.3 Workflow of Project

The study's methodology was centered on creating and putting into practice a solar water quality monitoring system with IoT for fish farming. This system used solar energy for the main power supply with a backup battery, and to make sure the battery did not overcharge, a solar charge controller was used too. This system also used two microcontrollers, the Arduino UNO and the ESP32, to control the sensor and make sure it was an IoT system. The sensors used in this system are a pH sensor, a temperature sensor, a turbidity sensor, and a dissolved oxygen sensor. LCDs are also used to show the result from the sensor, and the result is also shown in the Blynk app. The overall process of the device is shown by a flowchart in Figure 3.3 below.

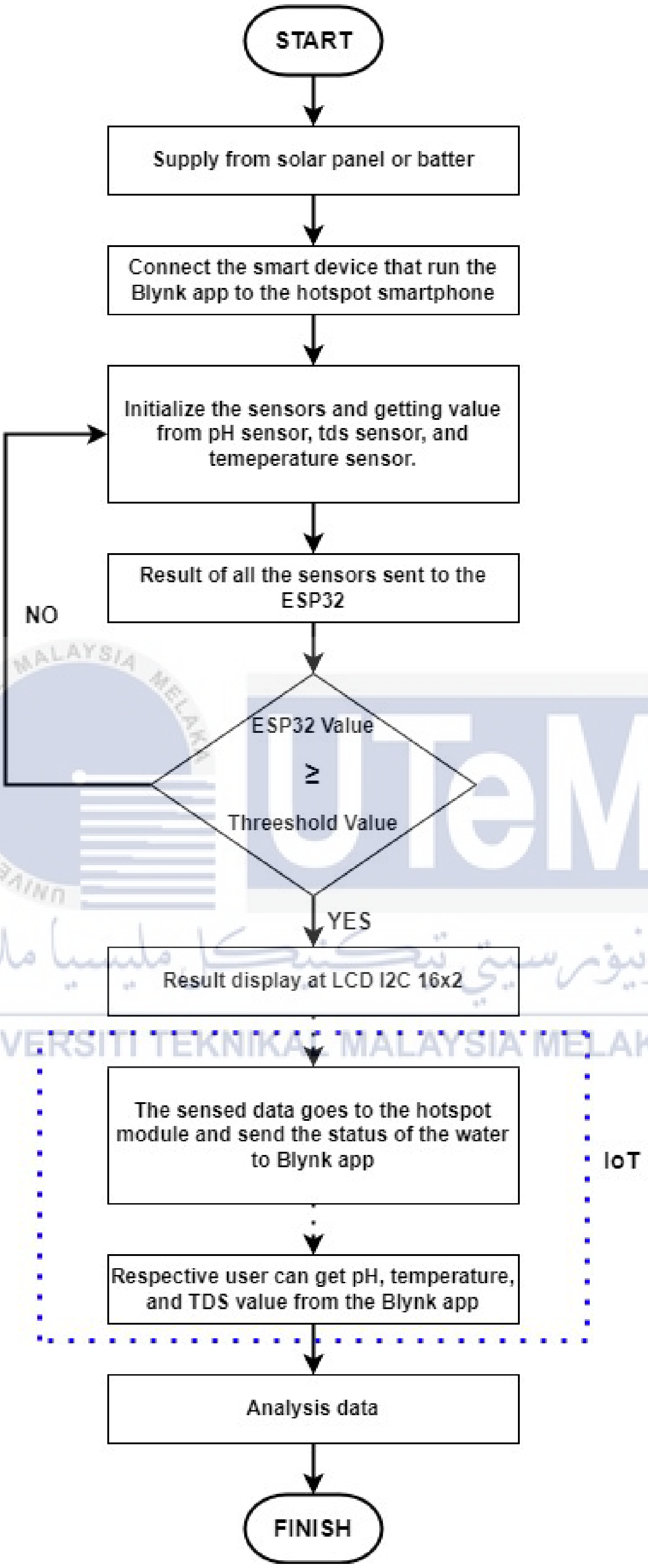


Figure 3.3 Flowchart of the system

3.4 Solar Panel System Development

3.4.1 Solar Panel

Figure 3.4 Solar Panel

Table 3.1 Technical Specification of Solar Panel

Polycrystalline	
Model Number	HHGF10P (36)
Power Maximum	10W
Tolerance	±5%
Imp	0.58A
Vmp	17.50V
Isc	0.63A
Voc	21.24V
Nominal Operating Cell Temp	-40CTO +85°C
Dimension	350*240*17(mm)
Maximum System Voltage	1000V
Maximum Series Fuse Rating	15A

In Figure 3.4, a polycrystalline solar panel, which is also called a multicrystalline solar panel, is a photovoltaic module that turns sunlight into power. They are efficient and cost-effective. The process of making something starts with making high-purity silicon ingots using ways like the Czochralski method or the floating-zone method. Then, these blocks are cut into wafers, which are then etched to get rid of any impurities and make the surface smoother. Dopant diffusion uses phosphorus to make a negatively doped layer, while screen printing uses silver-based paste to make front contacts. A coating that doesn't reflect light lets more light in, and aluminum is added for the back touch. Sorted solar cells are linked together, put in an EVA case, and topped with tempered glass. Electrical plugs make it easy to connect something to the electrical system and set it up. Table 3.1 above shows the specifications of the solar panel used in this project.

3.4.2 Solar Charge Controller

Figure 3.5 Solar charge controller

Table 3.2 Technical Specification of Solar Charge Controller

W88-A	
Rated voltage	12V / 24V
Rated current	10A
Max. PV voltage	50V
Max. PV input power	130W (12V), 260W (24V)

In Figure 3.5, a solar charge controller is a component of solar power systems that controls the rate at which batteries are charged. It is a crucial component that permits the effective and secure charging of batteries using solar panels. When the solar panels make electricity, the charge controller controls how much current goes to the batteries. This keeps the batteries at the right amount of charge and keeps them from getting damaged by overcharging. It also keeps the batteries from being fully drained, which can shorten their lifespan. Table 3.2 above shows the specifications of the solar charge controller used in this project.

3.4.3 Battery

Figure 3.6 Sealed Lead Acid Battery

A sealed lead acid (SLA) battery with a 12V and 7.2AH value is a type of rechargeable battery that is used in many ways. The 12V sign stands for the battery's nominal voltage, which is about 12 volts when the battery is fully charged. The 4.5 AH (ampere-hour) number of the battery shows how much power it can hold for a certain amount of time. This battery, which has a capacity of 4.5 AH, is often used in small electronics and other low power uses. Because the battery is sealed and can't leak liquid, it doesn't need to be taken care of and is safer to use. Because it has 4.5 AH, it can save a lot of energy, which makes it good for uses that don't need as much power. The example of a sealed lead acid battery is shown in Figure 3.6.

3.5 To Fabricate Solar Water Quality Monitoring System with IoT for Fish Farming

Figure 3.7 below shows the block diagram of fabricated solar water quality monitoring system with IoT for fish farming.

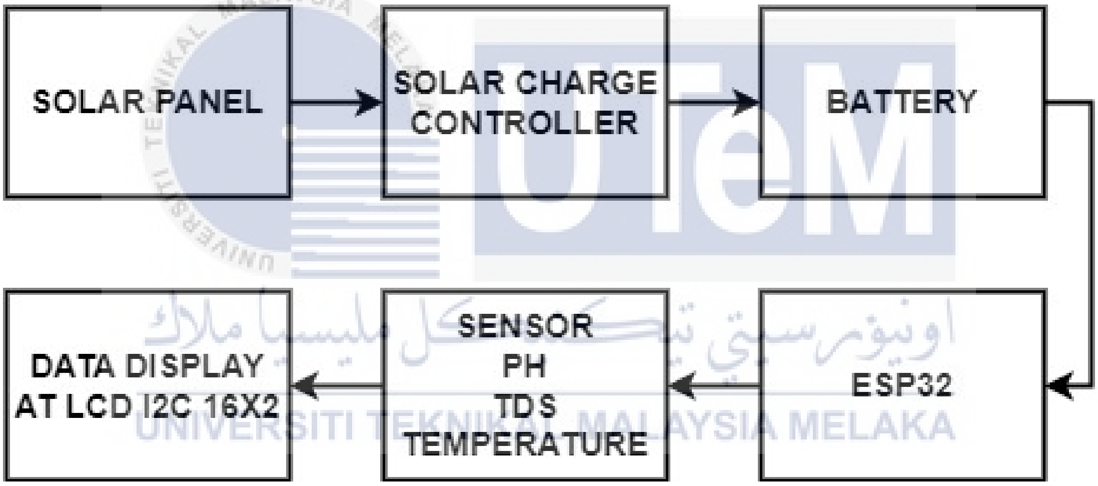


Figure 3.7 Block diagram of fabricate solar water quality monitoring system with IoT for fish farming

3.5.1 ESP32

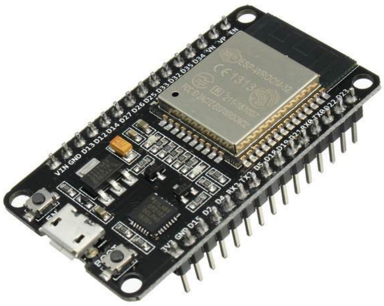


Figure 3.8 ESP32

The ESP32 is a popular microprocessor made by Expressive Systems. It is used for a lot of different things, like Internet of Things (IoT) gadgets, home automation, robotics, and more. Figure 3.8 above shows an example of an ESP32. The ESP32 is a powerful microcontroller with a dual-core processor, Wi-Fi and Bluetooth connectivity, a wide range of peripheral ports, and a lot of memory for storing programs and handling data. One of the best things about the ESP32 is that it already has Wi-Fi and Bluetooth built in. It works with a variety of Wi-Fi standards, such as 802.11b/g/n and 802.11ac, which lets it connect to local networks and the internet without any problems. Both regular Bluetooth and Bluetooth Low Energy (BLE) can be used with the Bluetooth adapter.

3.5.2 DS18B20 Waterproof Digital Temperature Sensor

Figure 3.9 Temperature sensor

Figure 3.9 shows the temperature of the sensor used in this project. An accurate measurement of water temperature requires a "water temperature sensor." It is made to be put in water and give temperature information in real time. The main part of a temperature monitors that measures temperature is a thermistor. It is a type of resistor whose resistance changes with the temperature. Most of the time, platinum, nickel, or titanium are used to make thermistor in water temperature monitors.

3.5.3 Analog pH Sensor

Figure 3.10 pH sensor

The main job of a pH sensor is to measure the pH level of a solution in a dependable and accurate way. It does this by turning the electrical potential made by the hydrogen ions in the solution into a number that corresponds to the pH. A glass electrode and a reference electrode are what make up the sensor. The main part that is used to measure pH is the glass electrode. It is a thin, sensitive barrier made of glass that only reacts with hydrogen ions. When the glass electrode is put into a solution, the hydrogen ions in the solution cause a potential difference across the glass membrane. This difference in potential is related to how high or low the pH level of the solution is. A pH sensor's job is to correctly measure the pH level of a solution. It does this by using a glass electrode and a reference electrode to measure the difference in potential caused by the hydrogen ions in the solution. It gives useful information for controlling processes, making sure quality is good, and doing scientific research in a wide range of industries and uses. Figure 3.10 above shows an example of the pH sensor.

3.5.4 TDS (Total Dissolved Solids) Sensor

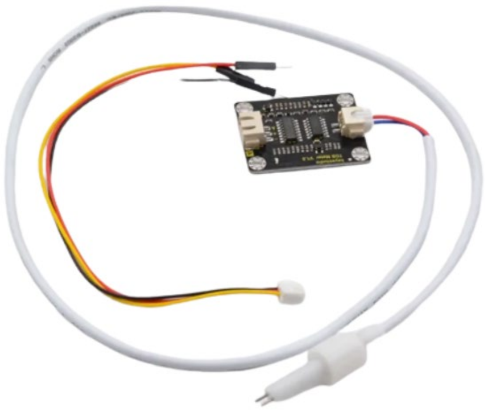


Figure 3.11 TDS Sensor

Total Dissolved Solids (TDS) as shown in Figure 3.10 serve as a crucial indicator of water purity, representing the quantity of soluble solids dissolved in one liter of water in milligrams. The TDS value, measured in parts per million (ppm) or milligrams per liter (mg/L), directly correlates with water purity—higher TDS values indicate a greater concentration of dissolved solids and potentially impure water. This metric finds practical applications in testing and monitoring residential water, hydroponics, and various water quality assessments. TDS encompasses both organic and inorganic compounds in molecular, ionic, or microgranular form. The lower the TDS value, the purer the water, making it a valuable tool for assessing water quality. For instance, reverse osmosis cleaned water typically registers a TDS value between 0 and 10, while tap water, depending on geographical locations, may range between 20 and 300. The significance of TDS in evaluating water purity is underscored by its widespread use and the correlation between TDS values and water quality.

3.5.5 LCD 16X2

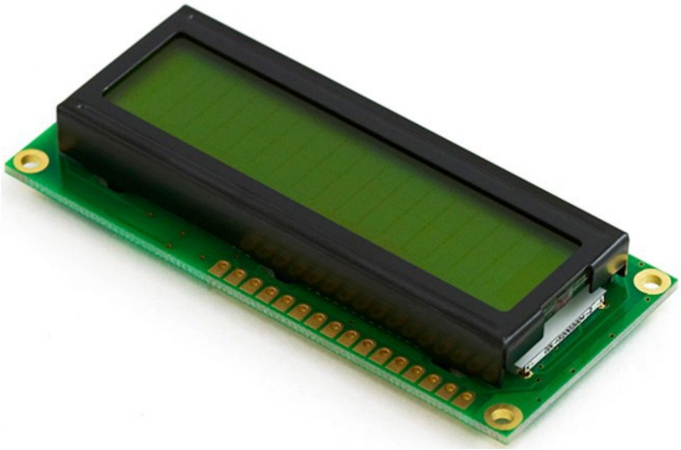


Figure 3.12 LCD 16x2

The LCD Backlight Display Module is a common display module that has a 16x2 LCD and a backlight like in Figure 3.12 above. This module lets people put letters, numbers, symbols, and simple pictures on the screen. The LCD has a 16x2 format that can show 16 columns and 2 rows of characters. This is one of its most interesting features. The I2C (Inter-Integrated Circuit) interface is used to talk between the module and other devices, like microcontrollers or single-board computers. When compared to parallel connections, the I2C interface needs fewer pins, which makes it easier to use. Also, the LCD module has a built-in LED backlight that makes the characters on the monitor easier to see. The backlight can be set separately from the characters, so users can change the brightness or turn it on or off depending on what they need.

3.5.6 Breadboard

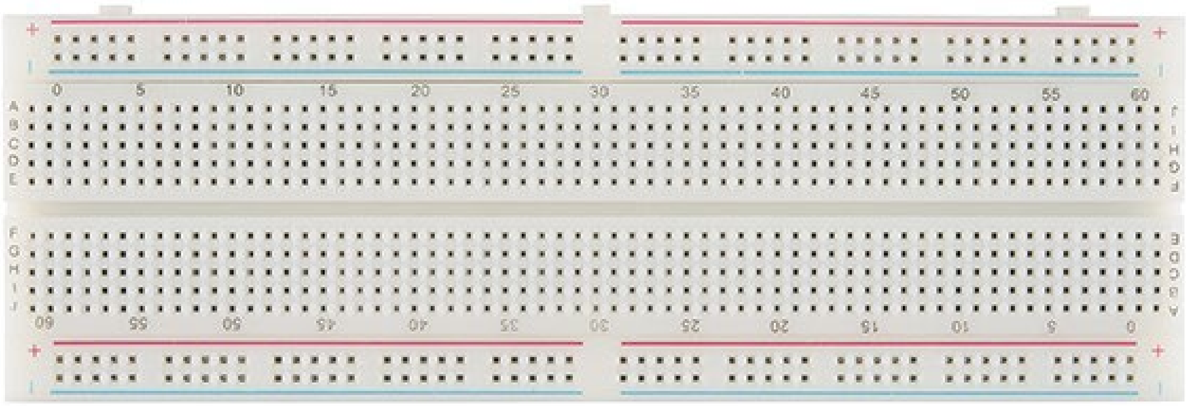


Figure 3.13 Breadboard

Breadboards are temporary boards for constructing electronic circuitry. 24-gauge solid wire, not stranded wire, is used to connect circuits, and it is compatible with most breadboards. Kits may occasionally be produced with various colors and fixed lengths designed to fit breadboards. Figure 3.13 above is an example of a breadboard.

3.5.7 Jumper Wires

Figure 3.14 Jumper Wires

Jumper wires are simply wires with connector pins on both ends, allowing them to connect two places without soldering. Typically, jumper wires are used with breadboards and other prototyping equipment to simplify circuit modifications. Although jumper wires are available in several colors, the colors have no significance. This means that a red jumper wire is identical to a black one from a technical standpoint. However, the colors can be used to distinguish between other types of connection, such as ground and power. Figure 3.14 above is an example of jumper wires.

3.5.8 Circuit Diagram

Figure 3.16 shows the circuit diagram that consists of all components and the connections in the device. The circuit diagram was constructed using Fritzing, the online circuit design application.

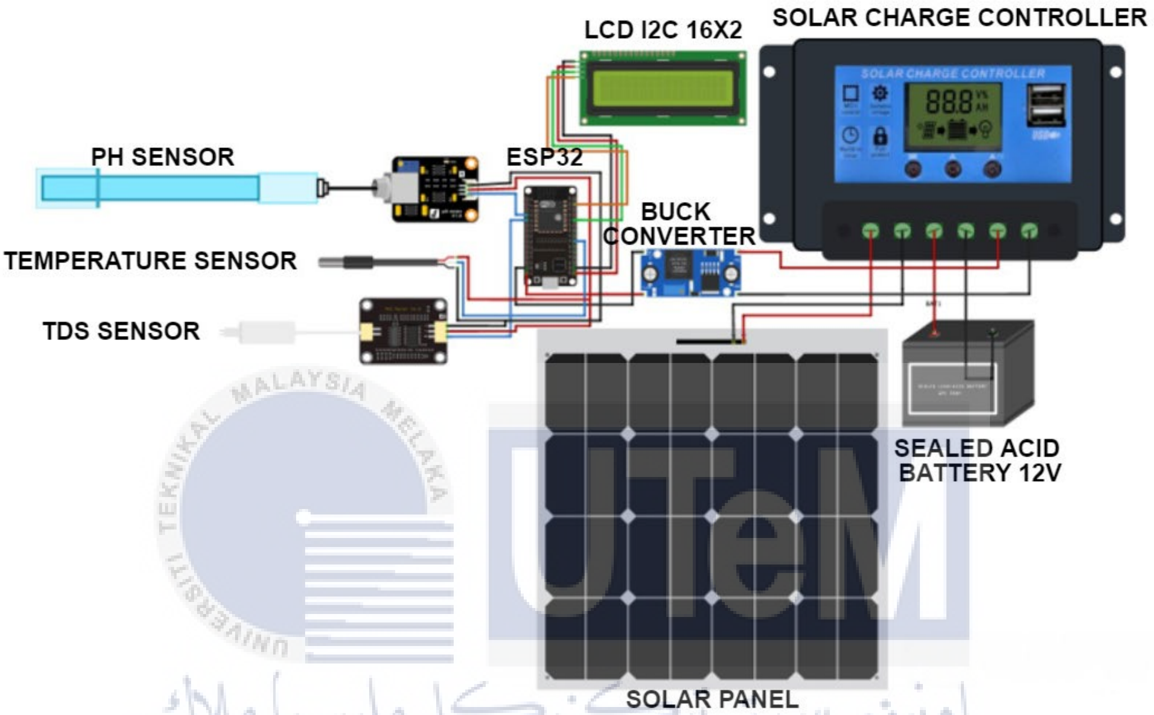


Figure 3.15 Circuit diagram of the project

3.6 Software Development

Figure 3.16 below shows the block diagram of software development.

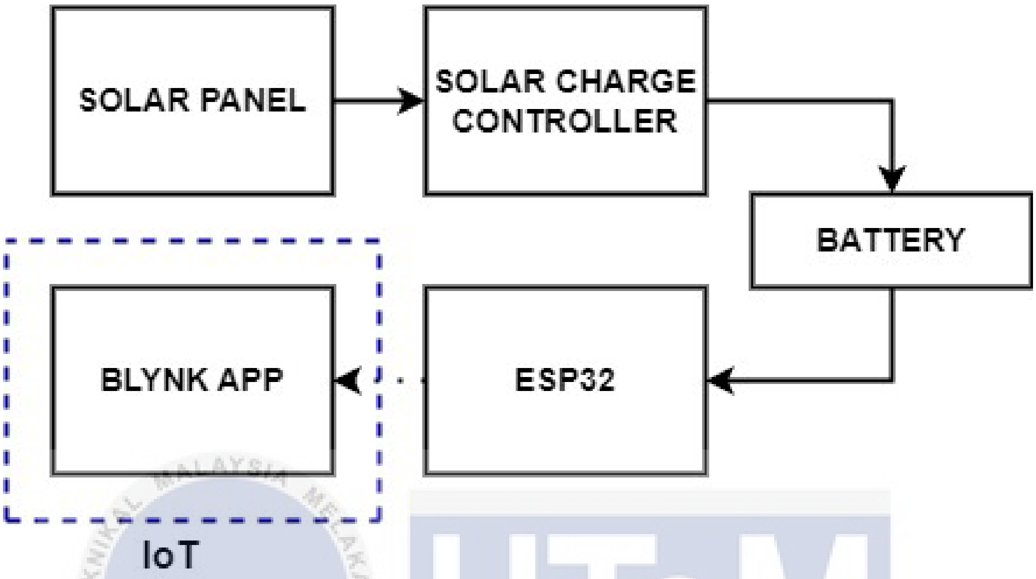


Figure 3.16 Block diagram of software development

3.6.1 Arduino IDE

The Arduino Integrated Development Environment (IDE) is a comprehensive software tool that encompasses various components for programming and interacting with Arduino hardware. Its features include a text editor for code writing, a message box offering feedback during tasks, a text console displaying output data and error messages, and a toolbar with frequently used task buttons and menus. The IDE links seamlessly with Arduino hardware to facilitate communication and program uploads. Sketches, which are programs written using the IDE, are composed in the text editor, and saved with the Ino file extension. The editor provides essential functions like copying, pasting, and text search and replace. The configured board and serial port are visible in the window, and the toolbar allows for tasks such as validating and uploading programs, generating, opening, and saving sketches, and launching the serial monitor. The Arduino IDE application provides a user-friendly interface for coding and interacting with Arduino hardware. The Arduino IDE application shown in Figure 3.14.

Figure 3.17 Arduino IDE application

3.6.2 Blynk Application

Blynk is an Internet-of-Things platform for iOS or Android smartphones that allows users to remotely operate devices like Arduino, Raspberry Pi, ESP32, and NodeMCU. Using this application, users may compile and provide the right address on the various widgets to construct a graphical interface or human machine interface (HMI). It can store data, visualize it, show sensor data, remotely operate hardware, and perform many other fascinating things. Example of Blynk Application is shown in figure 3.15 below.

Figure 3.18 Blynk Application

3.7 Four Water Sample Measurement

3.7.1 Procedure

To power up the device, as shown in Figure 3.19 below, a power supply must be connected to the ESP32. In this case, a 10W polycrystalline solar panel was used as the power supply. Afterward, connect the mobile hotspot to the ESP32 board, which is to make sure the Blynk app is in standby mode. Next, all the sensors must be soaked in water to initialize the sensors and get the values of TDS, pH, and temperature from the sensors. The sensors' results are relayed to the ESP32 board. In addition, the sensed data is sent to the mobile hotspot, which then notifies the Blynk app of the water's state. Lastly, from the Blynk application display, the appropriate user may obtain the pH, TDS, and temperature values.

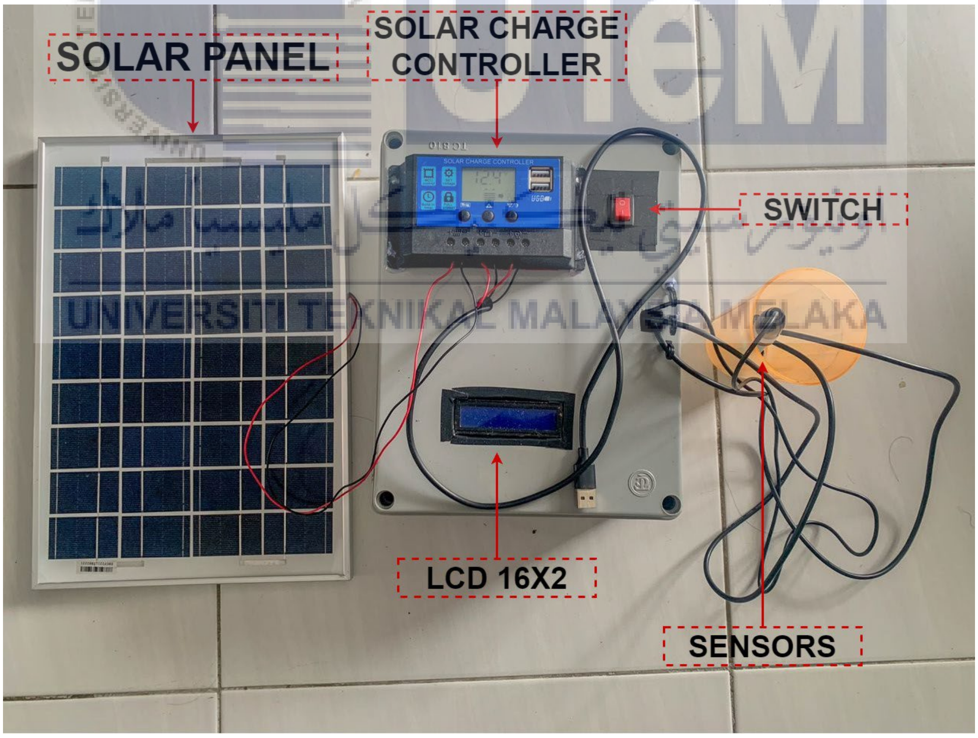


Figure 3.19 Solar Water Quality Monitoring System with IoT

3.7.2 Water sample

Table 3.3 below shows four water samples for measurement. It's been taken in different places.

Table 3.3 Four water sample for measurement

	SAMPLE
A	Tasik UTeM
B	Tasik Ayer Keroh
C	Kolam Ikan 123 Batu Arang
D	Kolam Pancing Seksyen 24, Shah Alam

Figure 3.20, Figure 3.21, Figure 3.22, and Figure 3.23 below show the sample of water taken at Tasik UTeM, Tasik Ayer Keroh, Kolam Ikan 123 Batu Arang, and Kolam Pancing Seksyen 24, Shah Alam.

Figure 3.20 Sample water of Tasik UTeM

Figure 3.21 Water sample of Tasik Ayer Keroh

Figure 3.22 Water sample of Kolam Ikan 123 Batu Arang

Figure 3.23 Water sample of Kolam Pancing Seksyen 24, Shah Alam

3.8 Summary

This chapter focuses on a specific equipment model and the execution of the project using that equipment. This project is based on microcontrollers. All the gadgets are shown with correct model information and accompanying images. This chapter also contains a model prototype for achieving primary and secondary project objectives. Using this sort of technology to accomplish the project's objective is intuitive.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

The increasing demand for sustainable aquaculture practices has led to the development of innovative technologies to monitor and maintain optimal water quality conditions in fish farming systems. In this study, the results and discussion of the implications of a solar water quality monitoring system integrated with the Internet of Things (IoT) for efficient monitoring of water parameters in fish farms were presented. This system aims to provide real-time data on essential water quality parameters, ensuring the well-being and growth of fish populations while minimizing manual labor and reducing environmental impacts. The following sections outline the findings and discuss the implications of implementing this system in fish farming practices.

4.2 Solar Measurement Data

Tests and measurements on the solar panel were conducted from 12:00 to 16:30, as shown in Table 4.1 below. The panel solar is connected to the solar charge controller, and the measurement was taken by a multimeter. The solar panel used in this measurement is polycrystalline, and the maximum power is 10 W.

Table 4.1 Data of Solar Panel

Time	Current (I)	Voltage (V)	Power (W)
12:00	0.52	18.6	9.67
12:30	0.52	19.7	10.24
01:00	0.34	19.2	6.53
01:30	0.38	18.6	7.07
02:00	0.43	19.4	8.34
02:30	0.29	18.9	5.48
03:00	0.25	18.8	4.70
03:30	0.06	18.9	1.14
04:00	0.21	15.3	3.21
04:30	0.15	14.5	2.18

From Table 4.1 above, the peak power output occurs around 12:30, with a power value of 10.24 W, indicating that this is the best time for solar energy production. A voltage of 19.7 V and a current of 0.52 A are connected to this peak. Throughout the day, power production decreases and reaches its lowest point around 03:30. This decrease might be caused by things like shifting incidence angles or waning solar intensity. Around 04:00 to 04:30, power was increased and decreased which is from 3.21 W to 2.18 W. As a reminder the power values vary throughout the day because of indicating changes in solar irradiance or other environmental factors affecting the solar panel's performance like cloud shadow. The data is presented in Figure 4.1 for current, Figure 4.2 for voltage, Figure 4.3 for power, and Figure 4.2 below shows some of the components that were used to collect the data.

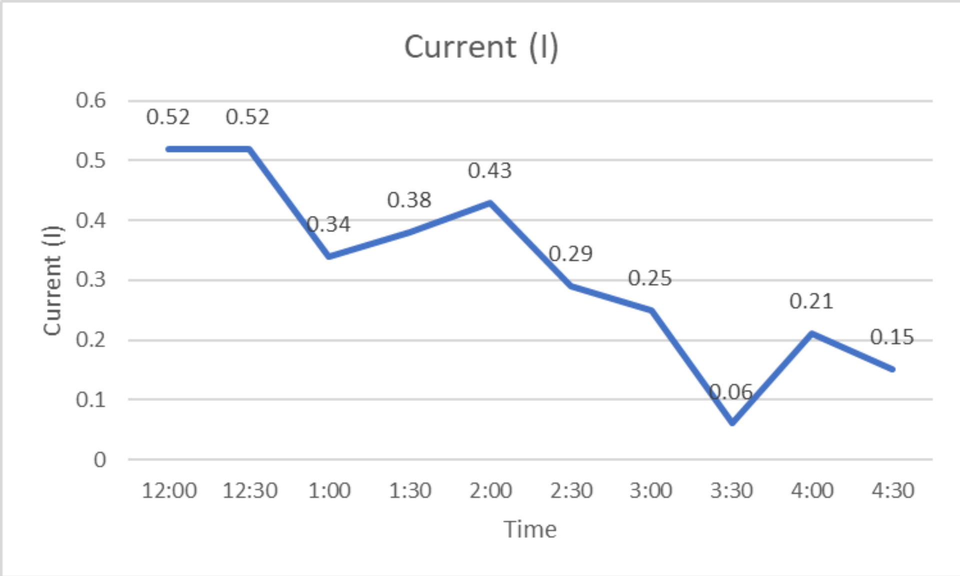


Figure 4.1 Graph of Current

Figure 4.1 above shows the graph of current from a 10-kW solar panel against time from 12:00 to 04:30. At the initial moment, precisely at 12:00, the numerical value is zero. The present level is reasonably constant at 0.52 until 01:00. During the time interval from 01:00 to 02:00, there is a decline in the electric current, dropping from 0.52 to 0.34. Between 02:00 and 03:00, there is a fluctuation in the current, characterised by a pattern of lowering and then increasing levels. Following 03:00, there is a significant decline in the flow of electric current, reaching its lowest point of 0.06 at 03:30. The current subsequently increases, reaching a value of 0.21 at 04:00 and 0.15 at 04:30.

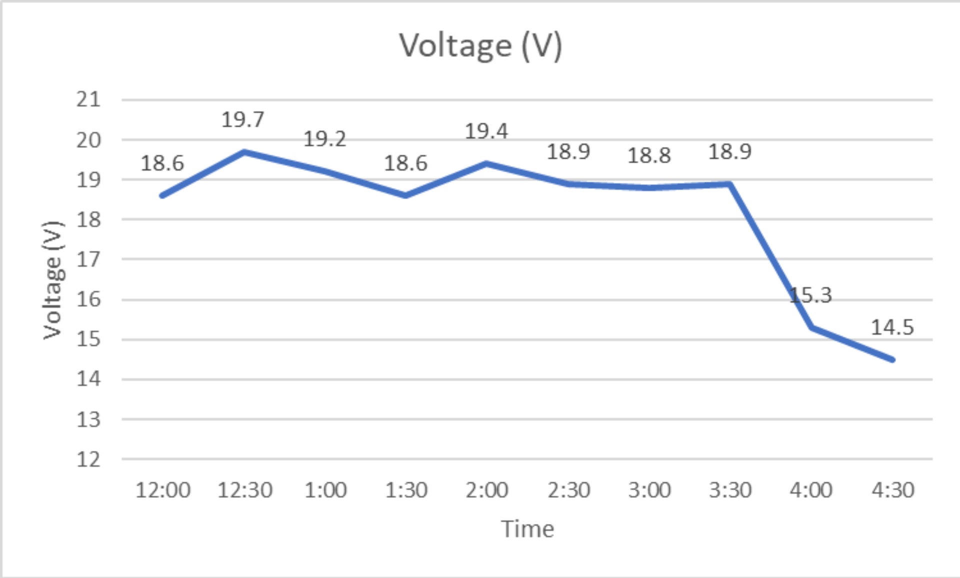


Figure 4.2 Graph of Voltage

Figure 4.2 above shows the graph of voltage from a 10-kW solar panel against time from 12:00 to 04:30. The voltage starts around 18.6 volts at 12:00 and fluctuates over the subsequent time points. There is an increase in voltage around 12:30, which is 19.7 volts, followed by a decrease at 01:00, which is 19.2 volts. The voltage remains relatively stable until around 03:30, where there's a slight increase and then a decrease. There's a significant drop in voltage from 18.9 volts at 03:30 to 15.3 volts at 04:00. The voltage continues to decrease to 14.5 volts at 04:30.

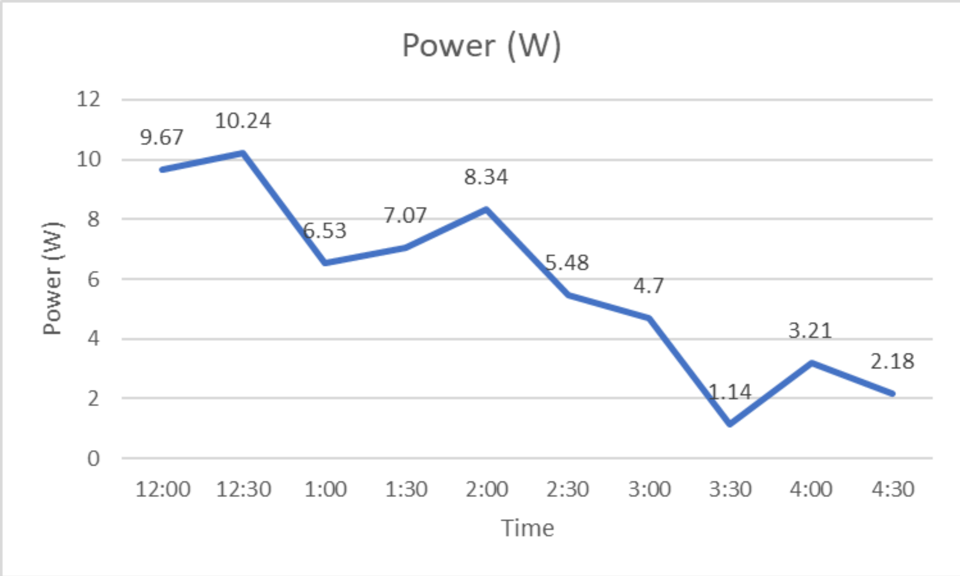


Figure 4.3 Graph of Power

Figure 4.3 above shows the graph of power from a 10-kW solar panel against time from 12:00 to 04:30. Power starts at 9.67 at 12:00 and increases to 10.24 at 12:30. Around 01:00, power was 6.53, there was a decrease in power, and at 01:30, there was an increase to 7.07. The power values fluctuate over the subsequent time points. There's a significant drop in power from 4.70 at 03:00 to 1.14 at 03:30. The power starts to increase again, reaching 3.21 at 04:00 and 2.18 at 04:30.

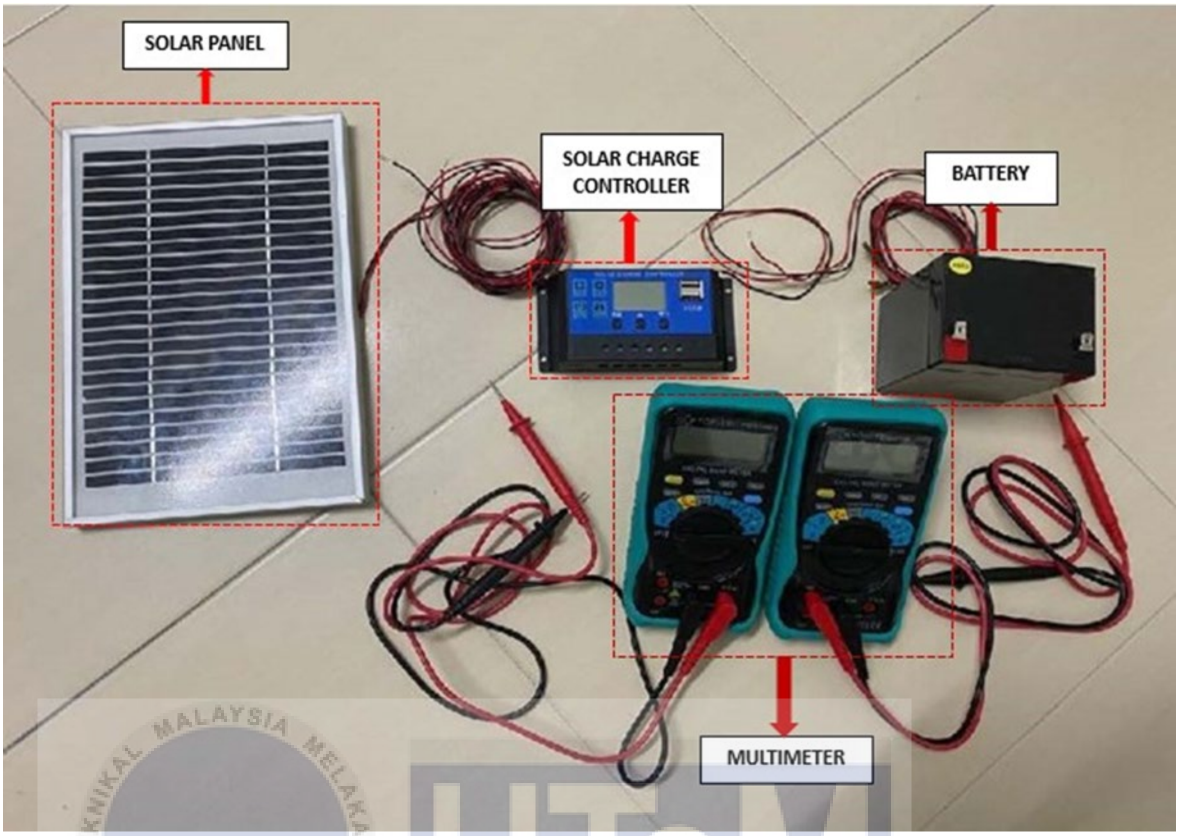


Figure 4.4 Experimental setup for solar data measurement

4.3 Results and Analysis for Fabricated Hardware

In this part, there will be illustration of all the data of pH, TDS, and Temperature reading collected for all water samples. Data of pH value, total dissolved solid and temperature from water samples of Tasik UTeM, Tasik Ayer Keroh, Kolam Ikan 123 Batu Karang, and Kolam Pancing Seksyen 24, Shah Alam were interpreted into graph using Microsoft Excel.

Table 4.2 Fishpond water standards

PARAMETERS	RANGE
pH	6.5 – 8.5
Temperature (°C)	25 -32
TDS (ppm)	0-1000

4.3.1 Water sample of Tasik UTeM

Table 4.2 below shows the data on pH, temperature, and TDS collected from water samples at Tasik UTeM. The data was taken ten times to get the average value, which is necessary to get the same value with a meter. From the data below, only TDS and temperature followed the guidelines for lake water, which range for temperature from 25 °C to 32 °C and for TDS from 0 ppm to 1000 ppm. The value of pH should range from 6.5 to 8.5, but the data shows 5.09 for the meter and 5.80 for the sensor.

Table 4.3 Data of pH, Temperature, and TDS (Tasik UTeM)

No.	pH		Temp (°C)		TDS (ppm)	
	METER	SENSOR	METER	SENSOR	METER	SENSOR
1	5.04	5.94	29.1	30	102	101
2	5.10	5.67	29.1	30	103	102
3	5.09	5.86	29.1	30	103	103
4	5.09	6.01	29.1	30	103	104
5	5.07	5.99	29.1	30	103	104
6	5.15	5.87	29.1	30	103	104
7	5.13	5.71	29.1	30	103	104
8	5.13	5.58	29.1	30	102	104
9	5.04	5.65	29.1	30	103	104
10	5.04	5.71	29.1	30	102	104
AVE	5.09	5.80	29.1	30	102.7	103.4

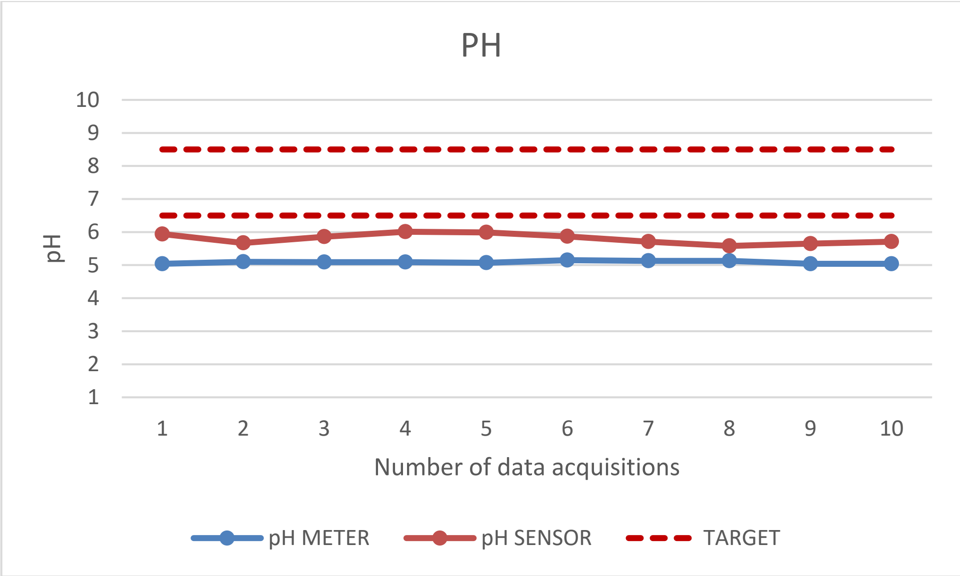


Figure 4.5 Graph of pH (Tasik UTeM)

Figure 4.5 above presents a comparison between pH measurements obtained using a pH meter and a pH sensor in the graph. The pH meter readings range from 5.04 to 5.15, while the pH sensor readings vary from 5.58 to 6.01. These values represent the acidity or alkalinity of the water sample in different instances. Differences between the pH meter and sensor readings may suggest variations in their precision or calibration. The average (AVE) pH values are calculated for both the pH meter and sensor. The average pH meter reading is 5.09, and the average pH sensor reading is 5.80. These average values give a general overview of the acidity level that each device measured over the course of the 10 measurements. Both values get the value below the target, which is 5, and the target is from 6.5 to 8.5.

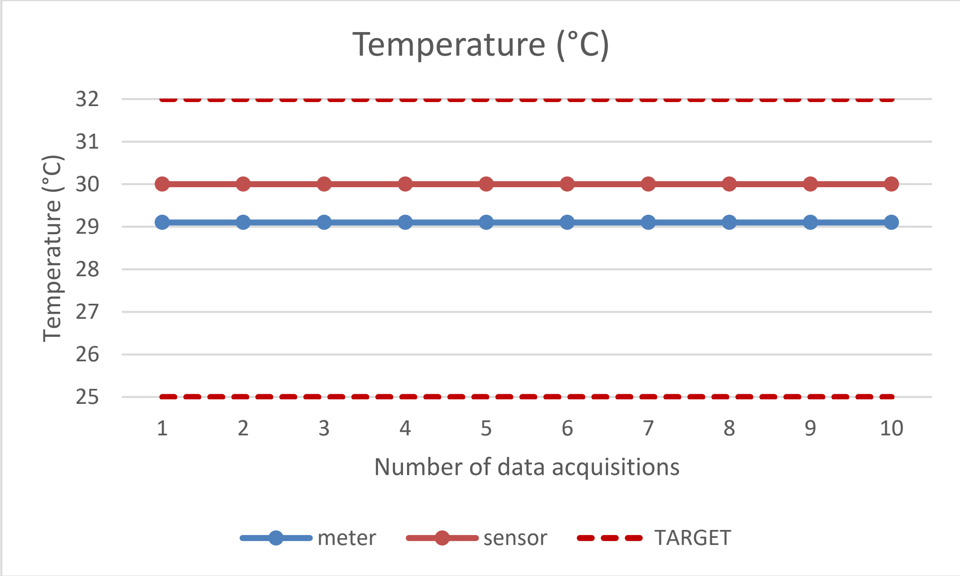


Figure 4.6 Graph of Temperature (Tasik UTeM)

The graph shown in Figure 2.1 depicts temperature measurements obtained from both a temperature meter and a temperature sensor. During the measurements, both the temperature meter and the temperature sensor consistently indicate the same results, with the meter recording a temperature of 29.1°C and the sensor recording a temperature of 30°C. The data reveals a consistent and unchanging temperature level, indicating that the observed environment is homogeneous and lacks substantial temperature variations. The mean temperature values for both the meter and the sensor are computed and reported as 29.1°C and 30°C, respectively. The mean values bolster the general stability and uniformity observed in the temperature observations. Both the value-form sensor and meter successfully achieved the intended range of 25 °C to 30 °C.

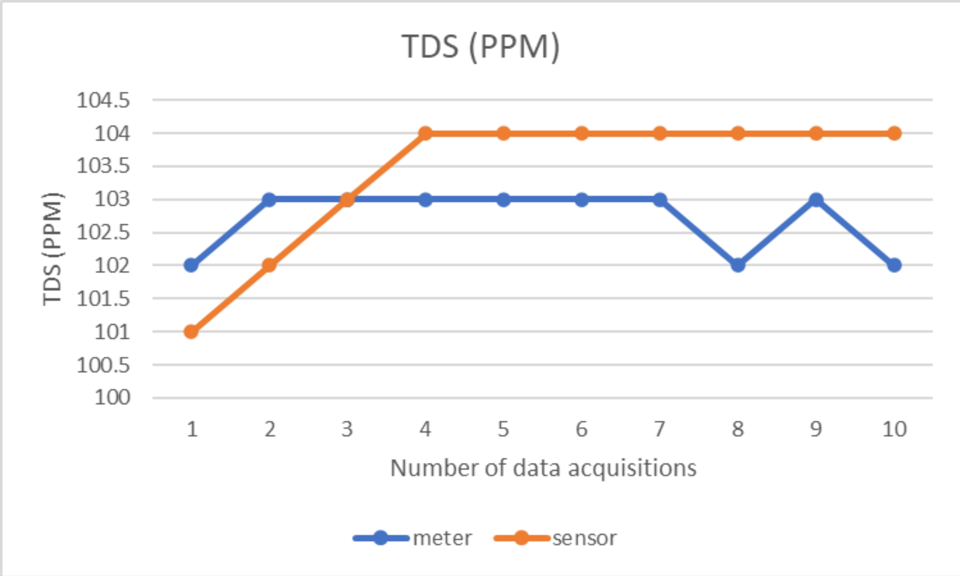


Figure 4.7 graph of TDS (Tasik UTeM)

Figure 4.7 above displays measurements of total dissolved solids (TDS) recorded by both a TDS meter and a TDS sensor. The TDS measurements are expressed in parts per million (ppm) for both the meter and the sensor. The TDS meter measures values within the range of 102 to 103 ppm, whereas the TDS sensor readings fluctuate between 101 and 104 ppm. The values indicate the level of dissolved solids in the water sample. The TDS meter consistently registers values approximately between 102 and 103 ppm, while the TDS sensor readings display a slightly broader range, ranging between 101 and 104 ppm. This implies that the sensor might exhibit a higher level of sensitivity to fluctuations in the concentration of dissolved solids in the water. The mean Total Dissolved Solids (TDS) readings for both the meter and the sensor are computed and reported as 102.7 parts per million (ppm) and 103.4 ppm, respectively, and the readings were in a good range.

4.3.2 Water sample of Tasik Ayer Keroh

The data on pH, temperature, and TDS collected from water samples at Tasik Ayer Keroh are presented in Table 4.3. The data was replicated ten times to obtain the mean value, which is essential for achieving consistency with a meter. Based on the provided data, only the TDS (total dissolved solids) and temperature measurements were within the recommended range for lake water. The acceptable temperature range for lake water is between 25 °C and 32 °C, while the acceptable TDS range is from 0 ppm to 1000 ppm. The pH value should ideally fall within the range of 6.5 to 8.5. However, the data indicates a reading of 5.15 for the meter and 5.23 for the sensor.

Table 4.4 Data of pH, Temperature, and TDS (Tasik Ayer Keroh)

No.	pH		Temp (°C)		TDS (ppm)	
	METER	SENSOR	METER	SENSOR	METER	SENSOR
1	5.17	5.34	29.3	29	70	66
2	5.15	5.42	29.3	29	70	62
3	5.15	5.13	29.3	29	68	58
4	5.15	5.39	29.3	29	68	59
5	5.15	5.17	29.3	29	69	64
6	5.15	5.38	29.2	29	70	65
7	5.15	5.11	29.2	29	69	63
8	5.15	5.15	29.2	29	70	61
9	5.15	5.12	29.1	29	68	58
10	5.15	5.07	29.1	29	70	59
AVE	5.15	5.23	29.23	29	69.2	61.5

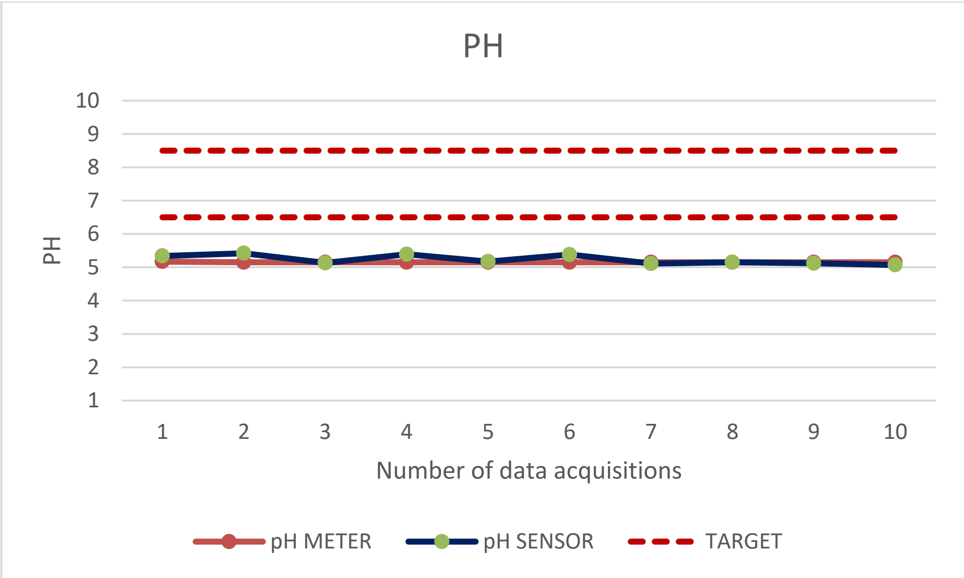


Figure 4.8 Graph of pH (Tasik Ayer Keroh)

From Figure 4.8 above, the pH meter consistently shows readings of 5.15. The pH meter's measurements exhibit a notable level of stability, indicating reliable and precise performance. Conversely, the pH sensor readings display a minor fluctuation, spanning from 5.07 to 5.42. Both devices regularly measure a pH level that is slightly alkaline, with an average value of 5.15 on the pH meter and an average reading of 5.23 on the pH sensor. The average reading of the pH meter in this instance is 5.15, while the average reading of the pH sensor is 5.23. The overall average results consistently show an alkaline pH environment for both instruments. Both readings do not reach the standards that should be from 6.5 to 8.5.

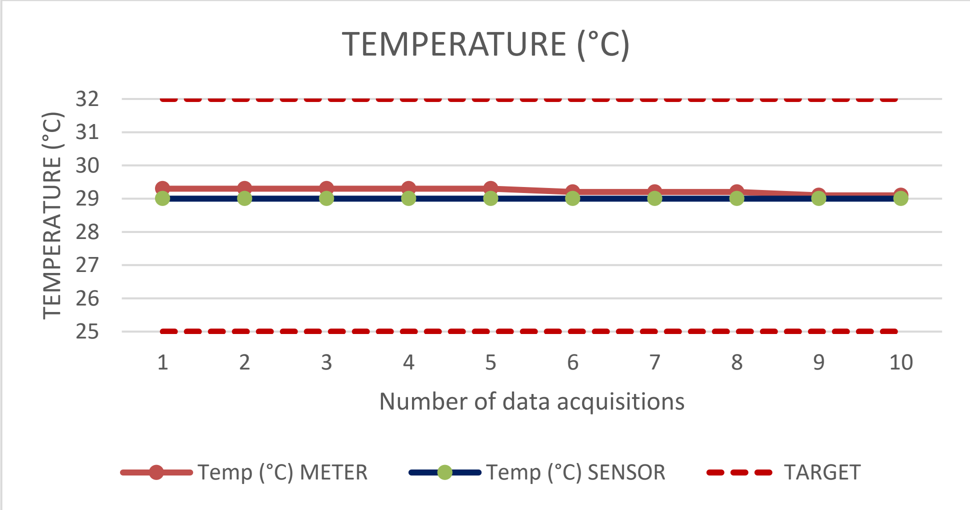


Figure 4.9 Graph of Temperature (Tasik Ayer Keroh)

Figure 4.9 above shows the graph of temperature against the number of data acquisitions. The temperature meter shows the first reading is 29.3 °C and starts decreasing slowly to 29.1 °C in the sixth reading. For reading the temperature sensor, constants start from the first reading to the last reading, which is 29 °C. Both readings still follow the existing standards, which are from 25 °C to 35 °C.

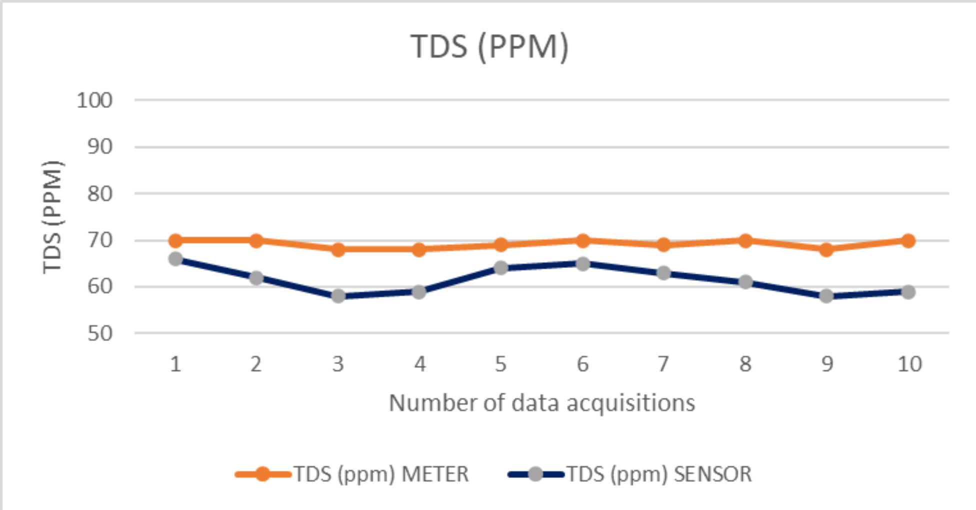


Figure 4.10 Graph of TDS (Tasik Ayer Keroh)

The graph from Figure 4.10 above shows the reading of TDS against ten of the data acquisitions. The first reading of the TDS meter is 70 ppm, which suddenly decreases to 68 ppm. After two readings showing 68 ppm, the fifth reading increased to 69 ppm and 70 ppm. This reading continued to decrease and increase for just one figure, and the average reading for the TDS meter is 69.2 ppm. The readings of the TDS sensor show that from the first reading to the third reading, they drop significantly, and from the third reading to the sixth reading, they rise again slowly. From sixth reading to last reading, they drop much slower. The average reading for the TDS sensor is 61.5 ppm. Both of the readings still follow the standards, which are below 1000 ppm.

4.3.3 Water sample of Kolam Ikan 123 Batu Arang

Table 4.4 below shows the data on pH, temperature, and TDS collected from water samples at Kolam Ikan 123 Batu Karang. The data was taken ten times to get the average value, which is necessary to get the same value with a meter. Kolam Ikan 123 Batu Karang is a freshwater fishpond that has standard readings for pH, temperature, and TDS. From the data below, only TDS and temperature followed the standards for fishponds, which range for temperature from 25 °C to 32 °C and for TDS from 0 ppm to 1000 ppm. The value of pH should range from 6.5 to 8.5, but the data shows 4.64 for the meter and 4.68 for the sensor.

Table 4.5 Data of pH, Temperature, and TDS (Kolam Ikan 123 Batu Arang)

No.	pH		Temp (°C)		TDS (ppm)	
	METER	SENSOR	METER	SENSOR	METER	SENSOR
1	4.66	4.70	29.7	29	59	57
2	4.63	4.73	29.7	29	57	58
3	4.56	4.59	29.7	29	58	55
4	4.55	4.57	29.7	29	55	59
5	4.65	4.60	29.7	29	53	58
6	4.70	4.80	29.8	29	51	55
7	4.68	4.69	29.7	29	58	53
8	4.65	4.68	29.7	29	56	58
9	4.65	4.67	29.7	29	54	58
10	4.65	4.79	29.7	29	54	58
AVE	4.64	4.68	29.71	29	55.5	56.9

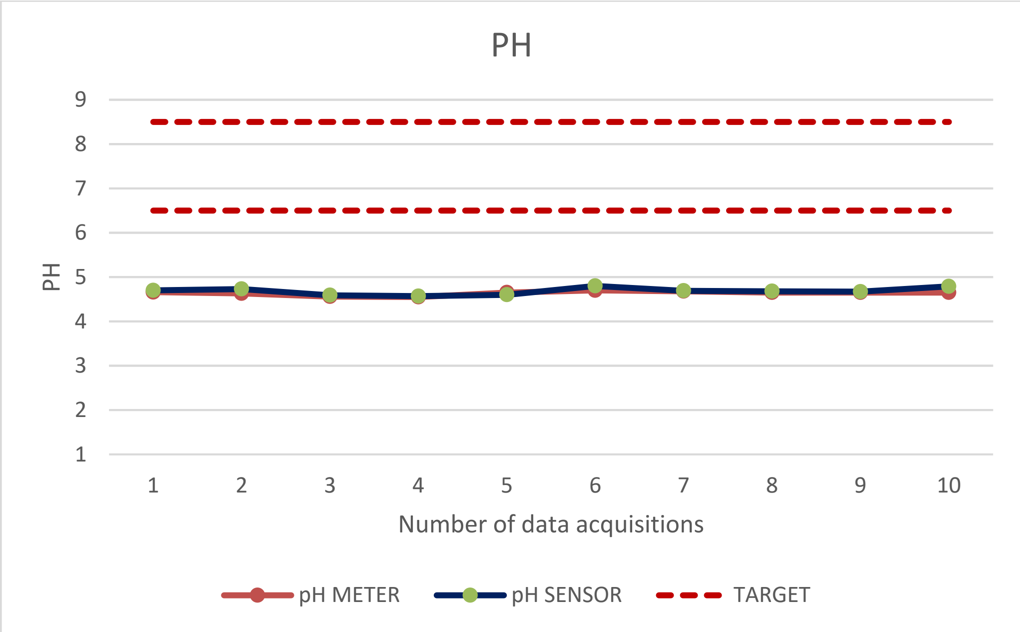


Figure 4.11 Graph of pH (Kolam Ikan 123 Batu Arang)

From figure 4.11 above, the graph has three lines of colour, which are blue for the pH sensor, orange for the pH meter, and red for the standard reading. The pH meter records values ranging from 4.55 to 4.70, while the pH sensor values fluctuate between 4.57 and 4.80. The pH sensor readings show a bit more variability, ranging from 4.59 to 4.80, with an average pH sensor reading of 4.68. This may indicate a minor sensitivity of the sensor to variations in the water's pH level. Both the pH meter and the pH sensor converge towards similar average values, which are 4.64 for the meter and 4.68 for the sensor. The data points would reveal a pattern of subtle fluctuations around the average values, illustrating the consistent but slightly variable nature of the pH readings.

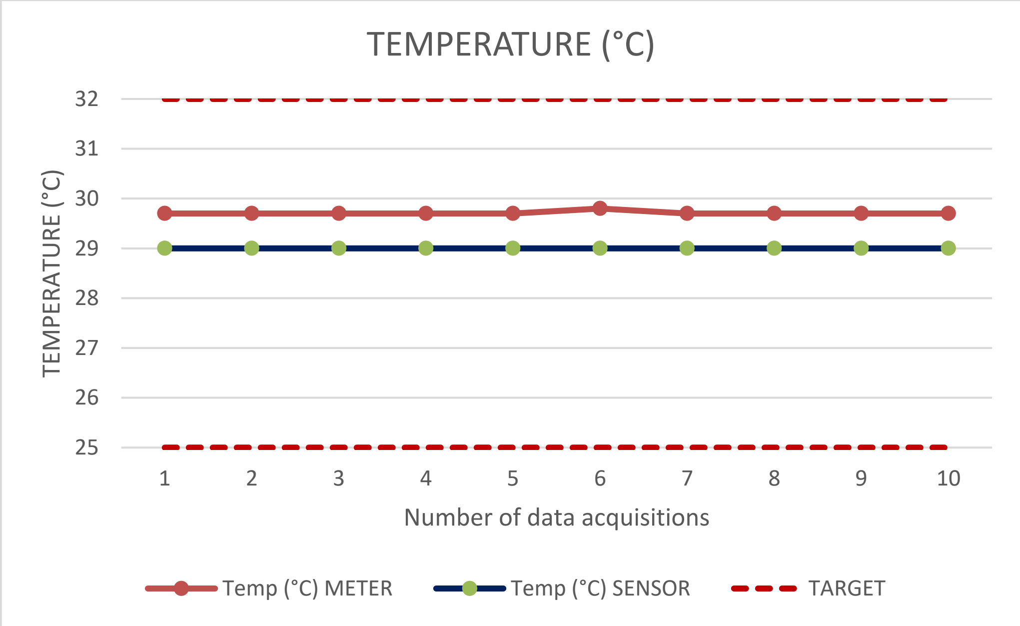


Figure 4.12 Graph of Temperature (Kolam Ikan 123 Batu Arang)

From figure 4.11 above, the graph has three lines of colour, which are blue for the temperature sensor, orange for the temperature meter, and red for the standard reading. The readings for the meter and sensor were in the range of a standard reading that is 25 °C to 32 °C. For reading temperature, the meter stayed at 29.7 °C, and at the sixth reading, the value increased to 29.8 °C. The reading for the temperature sensor was in a straight line, which means the reading is 29 °C.

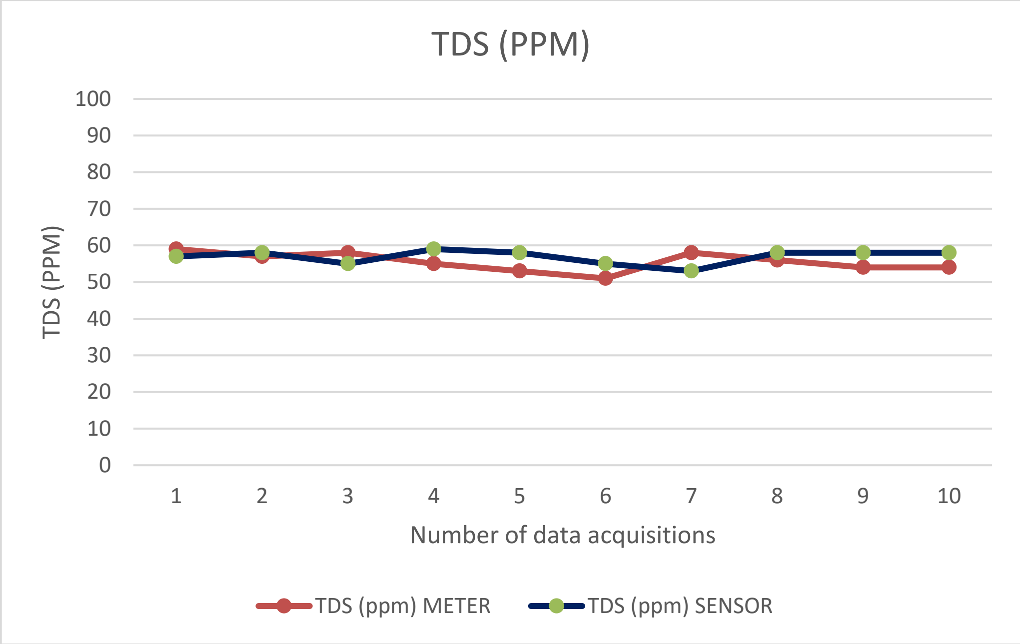


Figure 4.13 Graph of TDS (Kolam Ikan 123 Batu Arang)

The graph from Figure 4.13 above shows the reading of TDS against ten of the data acquisitions. The TDS meter records values ranging from 51 to 59 ppm, while the TDS sensor readings vary from 53 to 59 ppm. These values represent the concentration of dissolved solids in the water sample at different instances. The average (AVE) values for both the TDS meter and the TDS sensor converge towards 55.5 ppm and 56.9 ppm, and both of the readings still follow the standards, which are below 1000 ppm. Monitoring TDS levels is crucial for assessing water quality, and the provided data implies a relatively stable but dynamic composition of dissolved solids. The average values serve as valuable indicators of the overall TDS concentration during the observation period.

4.3.4 Water sample of Kolam Pancing Seksyen 24, Shah Alam

Table 4.5 below shows the data of pH, temperature, and TDS collected from water samples at Kolam Pancing Seksyen 24, Shah Alam. The data was taken ten times to get the average value, which is necessary to get the same value with a meter. Kolam Pancing Seksyen 24 is a freshwater fishpond that has standard readings for pH (6.5-8.5), temperature (25 °C -32 °C), and TDS (below 1000ppm). From the data below, only TDS and temperature followed the standards for fishponds. The value of pH should range from 6.5 to 8.5, but the data shows 4.96 for the meter and 5.02 for the sensor.

Table 4.6 Data of pH, Temperature, and TDS (Kolam Pancing Seksyen 24, Shah Alam)

No.	pH		Temp (°C)		TDS (ppm)	
	METER	SENSOR	METER	SENSOR	METER	SENSOR
1	5.01	5.15	29.9	29	208	213
2	4.98	4.90	29.8	29	200	201
3	4.95	4.95	29.7	29	207	210
4	4.88	5.01	29.7	29	205	217
5	4.89	4.97	29.6	29	201	208
6	4.90	5.05	29.6	29	206	207
7	4.96	4.99	29.7	29	207	205
8	5.00	5.05	29.7	29	205	202
9	5.01	5.10	29.6	29	2O9	203
10	5.01	5.05	29.6	29	204	205
AVE	4.96	5.02	29.69	29	204.8	207.1

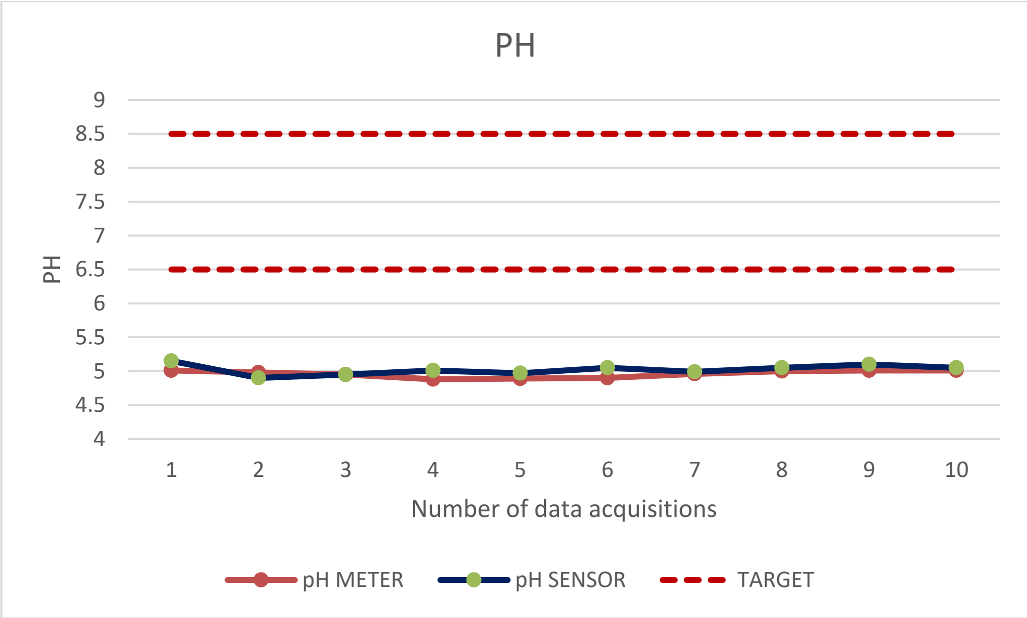


Figure 4.14 Graph of pH (Kolam Pancing Seksyen 24, Shah Alam)

Figure 4.14 shows the graph of pH readings for both the meter and sensor shows a pattern of slight variability around the average values. Measurements range from 4.88 to 5.01 for the pH meter and from 4.90 to 5.15 for the pH sensor. A line graph shows a consistent trend around the average values, indicating stability in the overall pH levels recorded. The average pH meter reading is 4.96, and the average pH sensor reading is 5.02. The graph reveals occasional divergence between pH meter and sensor readings, suggesting subtle differences in the devices' sensitivity to variations in the water sample's pH.

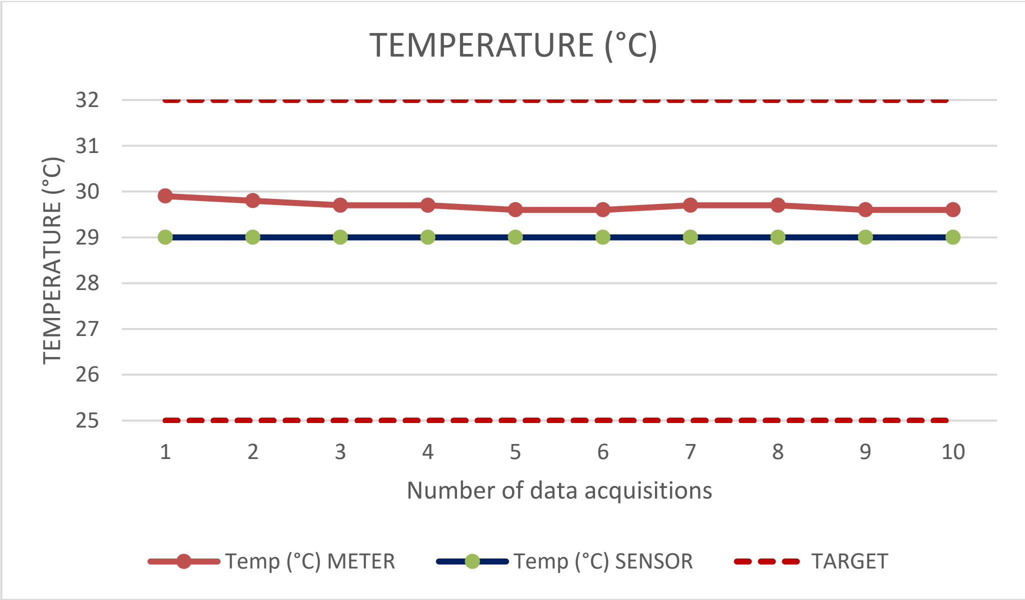


Figure 4.15 Graph of Temperature (Kolam Pancing Seksyen 24, Shah Alam)

Figure 4.15 shows the recorded temperature data illustrates remarkable consistency between the temperature meter and the sensor, with both consistently indicating a temperature of 29°C throughout the ten measurements. This uniformity suggests a stable and controlled environment, emphasising the reliability of both the temperature meter and sensor. The average temperature, calculated at 29.69°C, reaffirms the overall constancy observed in the individual measurements. The provided data underscores the reliability of both the temperature meter and sensor, showcasing their capacity to deliver accurate and consistent temperature measurements over the course of the observations and both reading still in a range of standards.

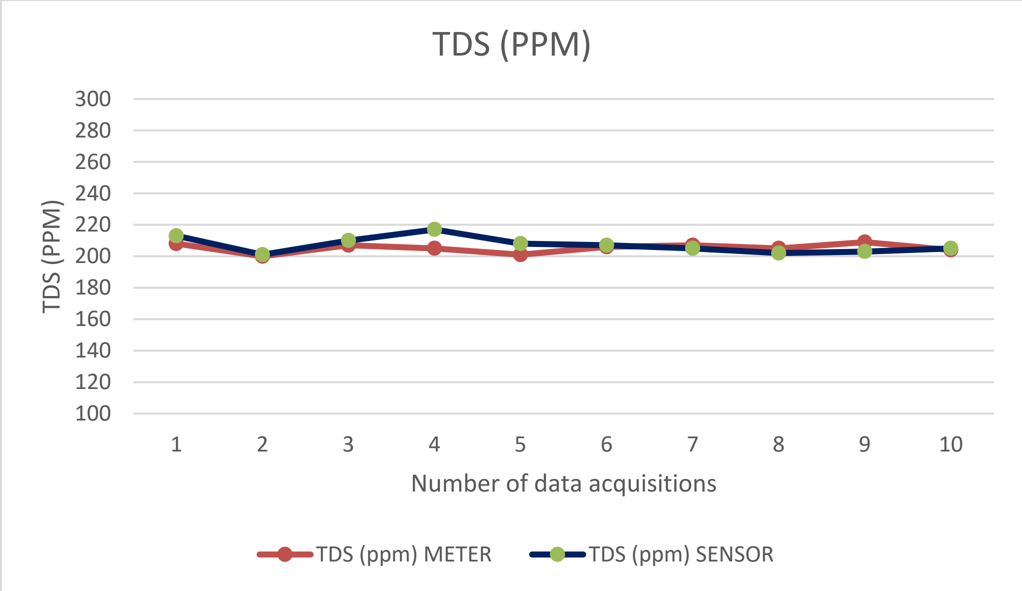


Figure 4.16 Graph of TDS (Kolam Pancing Seksyen 24, Shah Alam)

The graph in Figure 4.16 above shows the TDS values recorded by the meter fluctuate between 200 and 209 ppm, while the sensor readings vary from 201 to 217 ppm. This variability suggests dynamic changes in the concentration of dissolved solids in the water sample during the observation period. Despite the fluctuations, the average TDS values provide a consolidated view of the dissolved solids content. The average TDS meter reading is calculated at 204.8 ppm, while the average TDS sensor reading is slightly higher at 207.1 ppm.

4.4 Comparison for Four Water Sample

Table 4.7 Data for four water sample

SAMPLE	pH	Temp (°C)	TDS (ppm)
Tasik UTeM	5.80	30	103.4
Tasik Ayer Keroh	5.23	29	61.5
Kolam Ikan 123 Batu Arang	4.68	29	56.9
Kolam Pancing Seksyen 24, Shah Alam	5.02	29	207.1

The water quality at different locations exhibits variations according to the available data. Tasik UTeM has a pH of 5.80, indicating a somewhat acidic nature. It maintains a temperature of 30°C and has a total dissolved solids (TDS) concentration of 103.4 ppm. Meanwhile, Tasik Ayer Keroh exhibits a pH level of 5.23, a temperature of 29°C, and a total dissolved solids (TDS) measurement of 61.5 parts per million (ppm). The Kolam Ikan 123 Batu Arang has a pH level of 4.68, a temperature of 29°C, and a total dissolved solids (TDS) measurement of 56.9 parts per million (ppm). However, Kolam Pancing Seksyen 24 in Shah Alam has a pH level of 5.02, a temperature of 29°C, and a significantly higher total dissolved solids (TDS) measurement of 207.1 ppm.

4.4.1 Comparison of pH for four water samples

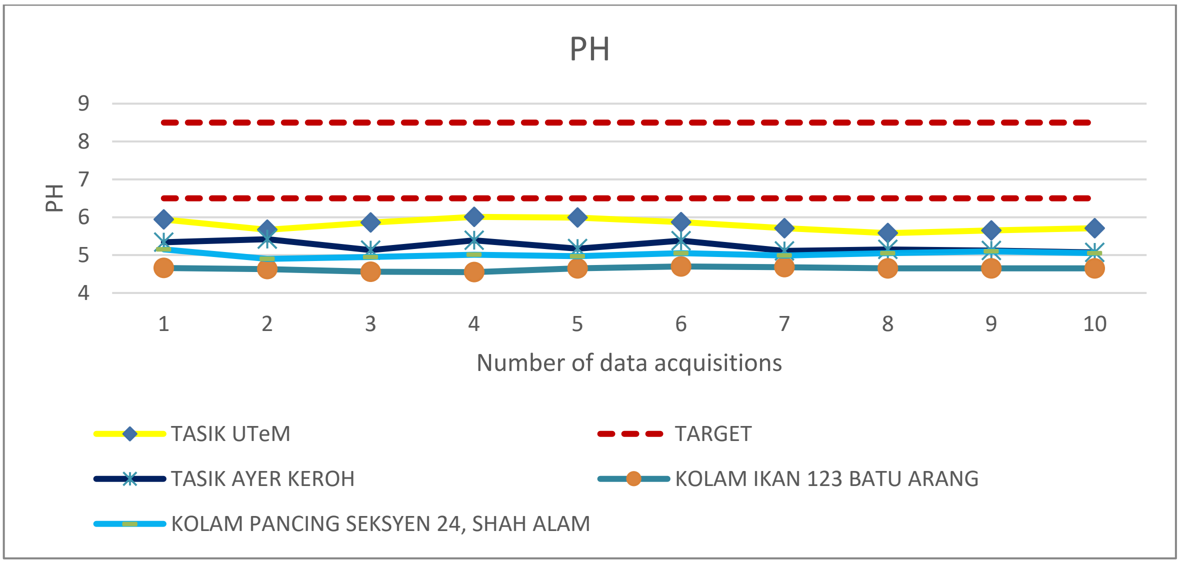


Figure 4.17 Graph of pH for four water samples

Figure 4.17 above shows the graph of pH for four water samples. The pH measurement of Tasik UTeM was 5.80, indicating a somewhat acidic characteristic. The pH of Tasik Ayer Keroh was measured to be 5.23, indicating that it falls within the acidic range. On the other hand, Kolam Ikan 123 Batu Arang exhibited a pH level of 4.68, indicating a higher acidity in the environment. Finally, the fishing pond in Section 24, Shah Alam, exhibited a pH level of 5.02, which added to the overall acidic pattern detected in these water samples. Although all the sample data does not conform to the standard for fishponds, the fish can still live, but they will quickly get diseases such as fungal infections and other physical damage. This dataset demonstrates the disparity in pH values among various aquatic sites, offering valuable insights into the water quality and likely environmental circumstances in these regions.

4.4.2 Comparison of temperature (°C) for four water samples

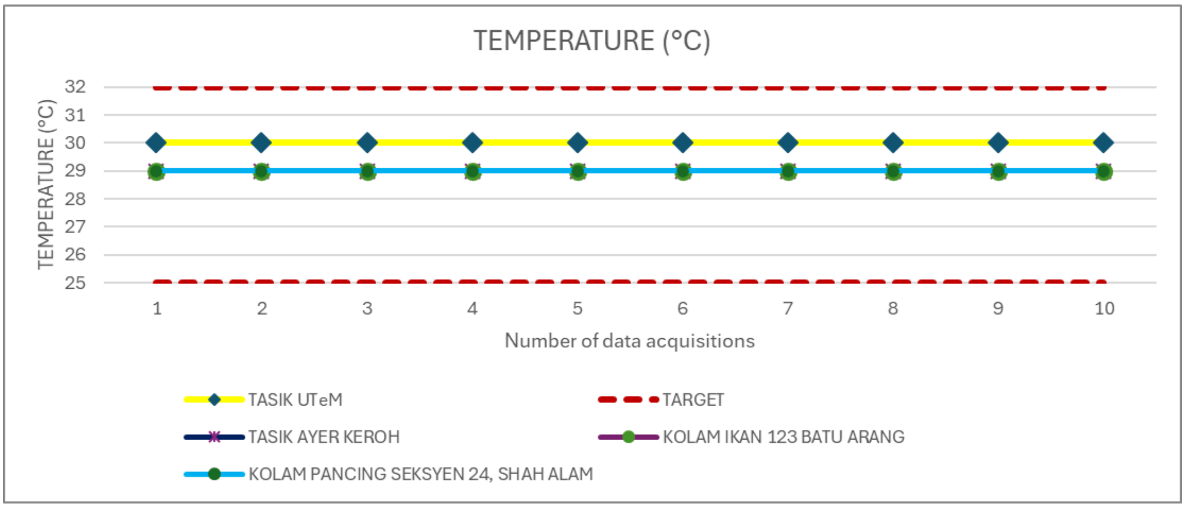


Figure 4.18 Graph of temperature (°C) for four water samples

Figure 4.17 above shows the graph of temperature (°C) for four water samples. The temperature recorded at Tasik UTeM was 30°C, suggesting a moderately warm water habitat. Tasik Ayer Keroh, Kolam Ikan 123 Batu Arang, Kolam Pancing Seksyen 24, and Shah Alam all recorded temperatures of 29°C, which were slightly lower. All sample data are within the safe range for fish, which is 25°C – 32°C. All the The temperature values indicate a comparable thermal profile across these distinct water bodies, with minor deviations possibly driven by geographical location, season, or local climate.

4.4.3 Comparison of TDS (ppm) for four water samples

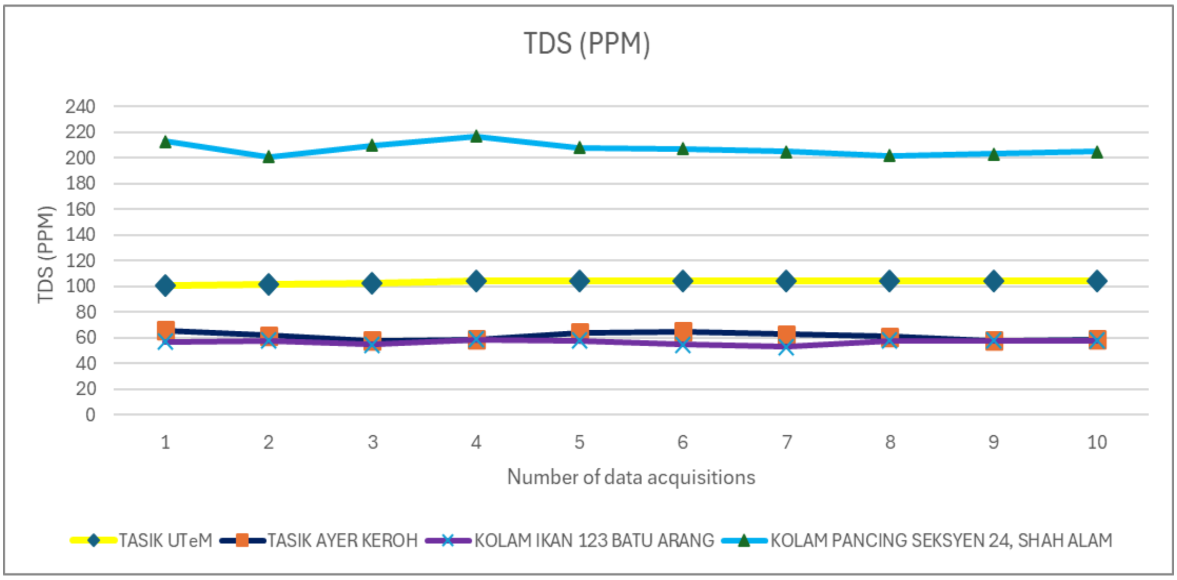


Figure 4.19 Graph of TDS (ppm) for four water samples

Figure 4.17 above shows the graph of TDS (ppm) for four water samples. All the water samples were in good condition because the reading was from 0 ppm to 1000 ppm. Tasik UTeM recorded a TDS level of 103.4 ppm, indicating a moderate concentration of dissolved solids. Tasik Ayer Keroh exhibited a lower TDS at 61.5 ppm, suggesting a comparatively lower presence of dissolved substances in its water. Kolam Ikan 123 Batu Arang displayed an even lower TDS of 56.9 ppm, indicating a relatively cleaner water composition. In contrast, Kolam Pancing Seksyen 24 and Shah Alam registered a higher TDS level of 207.1 ppm, pointing towards a potentially elevated concentration of dissolved solids in this water body. These TDS measurements contribute to understanding the water quality variations across these aquatic environments.

4.5 Summary

This chapter discusses the project's goals, progress, and results. Upon testing, it was found that the project was performed per the design requirements. It complied with the functional requirements. This chapter provided the needed system design, data analysis, result comparison, and interpretation. A few discrepancies were found and fixed throughout the assessment of the material. Data must be running numerous times to get the desired outcome.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the solar water quality monitoring system with IoT for fish farming has proven to be an excellent and useful project. Next, all three objectives of this project, such as investigating, fabricating, and analyzing the project to develop a device to collect and measure water quality data and analyzing the data using the numerical method, were successfully achieved. All the theories about this project are discussed, such as the related devices and theories, the process of project design and development, and the critical parts or components used for the electrical system.

5.2 Potential for Commercialization

The solar water quality monitoring system with IoT for fish farming has a lot of promise to become a business. It offers new ways to make aquaculture operations more sustainable and efficient. This project aims to enhance fish farming techniques by implementing a system that enables real-time monitoring of essential water quality indicators, including pH, temperature, and total dissolved solids (TDS). By providing precise data, the system empowers fish farmers to optimise environmental conditions for aquatic life.

Furthermore, this project will use a sustainable energy source, specifically solar power. The incorporation of solar panels into the monitoring system renders it environmentally sustainable and diminishes reliance on traditional energy sources, so presenting an appealing choice for environmentally aware fish producers.

In addition, IoT connectivity enables fish producers to remotely monitor and regulate water quality indicators. This function is crucial for farmers overseeing extensive aquaculture operations, allowing them to make prompt choices and modifications without needing to be physically there.

Lastly, the market is witnessing a growing need for sustainable practices. This is driven by the increasing worldwide demand for seafood that is obtained responsibly and produced in an environmentally friendly manner. Fish farmers that embrace eco-friendly techniques, such as utilising solar-powered systems for monitoring water quality, can gain a competitive advantage in the market.

In conclusion, this project effectively tackles crucial requirements in the aquaculture sector and is in line with the prevailing movements towards sustainability and technological advancement. The commercialization of this technology has the potential to yield advantages for both fish farmers and the aquaculture sector in its whole.

5.3 Future Works

The precision of the analyzed and collected results can be increased as follows for future improvement recommendations:

1. Use more precise sensors to collect water sample data.
2. Collect water sample data on the same day and at the same time interval to increase the precision of data analysis.
3. Avoid collecting data on water samples on rainy days because it will affect the data.

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APPENDICES

Appendix A Gantt chart of PSM 1

PROGRESS	WEEK												
	1	2	3	4	5	6	7	8	9	10	11	12	13
APPLICATION MENDELEY						MID SEMESTER BREAK							
DOWNLOAD JOURNAL													
PROBLEM STATEMENT													
OBJECTIVE													
ABSTRACT													
WRITING LITERATURE REVIEW													
FABRICATE METHODOLOGY													
COLLECT DATA & MEASUREMENT PRE-PROJECT													
CONCLUSION OF PRELIMINARY RESULT													
BUY COMPONENTS													
SUBMIT TO SV (DR. SUZIANA)													

Appendix B Gantt chart of PSM 2

PROGRESS	WEEK												
	1	2	3	4	5	6	7	8	9	10	11	12	13
BUY COMPONENTS						MID SEMESTER BREAK							
DESIGN THE WHOLE BODY OF THE PROJECT													
FINISH THE PROJECT DEVICE													
TEST THE PROJECT DEVICE													
ANALYSIS DATA													
RECORD THE RESULT													
COMPLETE THE REPORT													
DISSCUSS WITH SV ABOUT THE REPORT													
MAKE IMPROVEMENT TO THE REPORT													
SUBMIT TO SV													
PRESANTATION													

Appendix C Coding

```
#define BLYNK_PRINT Serial
#define BLYNK_TEMPLATE_ID "TMPL6ipFk605z"
#define BLYNK_TEMPLATE_NAME "Quickstart Template"
#define BLYNK_AUTH_TOKEN "3ePXsw6NApzv7RiUohIXw1D-6xQplKWY"

#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <OneWire.h>
#include <DallasTemperature.h>
#define TEMP 17 // ESP32 pin GIOP21 connected to DS18B20 sensor's DQ pin
#define PH 34
#define TdsSensorPin 35
#define VREF 3.3      // analog reference voltage(Volt) of the ADC
#define SCOUNT  30            // sum of sample point

char ssid[] = "uwais raffee";
char pass[] = "uwaisraffee";

LiquidCrystal_I2C lcd(0x27,16,2);
OneWire oneWire(TEMP);
DallasTemperature DS18B20(&oneWire);

float tempC; // temperature in Celsius
float calibration_value = 21.34;

int pHval = 0;
int buffer_arr[10],temp;

//TDS
int analogBuffer[SCOUNT];    // store the analog value in the array, read from
ADC
int analogBufferTemp[SCOUNT];
int analogBufferIndex = 0,copyIndex = 0;
float averageVoltage = 0,tdsValue = 0,temperature = 25;

unsigned long int avgValue;

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

 pinMode(TdsSensorPin,INPUT);
 DS18B20.begin();    // initialize the DS18B20 sensor
 Serial.println("Ready");
 lcd.init();
 lcd.backlight();
 delay(1000); //test the serial monitor
}

void loop()
```

```
{
 Blynk.run();

 //PH CODING
 for(int i=0;i<10;i++)
 {
    buffer_arr[i]=analogRead(PH);
    delay(30);
 }
 for(int i=0;i<9;i++) //sort the analog from small to large
 {
    for(int j=i+1;j<10;j++)
    {
      if (buffer_arr[i]>buffer_arr[j])
      {
        temp = buffer_arr[i];
        buffer_arr[i] = buffer_arr[j];
        buffer_arr[j] = temp;
      }
    }
 }

 avgValue=0;
 for(int i=2;i<8;i++)
 avgValue+=buffer_arr[i];
 float volt = (float)avgValue*3.3/4095/8;
 float ph_act = -21.3 * volt + calibration_value;

 Serial.print("pH Value:");
 Serial.print(ph_act,0);

 lcd.setCursor(3,1);
 lcd.print("pH:  " );
 lcd.println(ph_act);
 delay(1000);
 Blynk.virtualWrite(V3, ph_act);


//TDS CODING
static unsigned long analogSampleTimepoint = millis();
   if(millis()-analogSampleTimepoint > 40U)     //every 40 milliseconds,read
the analog value from the ADC
   {
     analogSampleTimepoint = millis();
     analogBuffer[analogBufferIndex] = analogRead(TdsSensorPin);    //read the
analog value and store into the buffer
     analogBufferIndex++;
     if(analogBufferIndex == SCOUNT)
         analogBufferIndex = 0;
   }
   static unsigned long printTimepoint = millis();
   if(millis()-printTimepoint > 800U)
   {
      printTimepoint = millis();
      for(copyIndex=0;copyIndex<SCOUNT;copyIndex++)
        analogBufferTemp[copyIndex]= analogBuffer[copyIndex];
```

```
      averageVoltage = getMedianNum(analogBufferTemp,SCOUNT) * (float)VREF / 
4095.0;
      // read the analog value more stable by the median filtering algorithm, 
and convert to voltage value
      float compensationCoefficient=1.0+0.02*(temperature-25.0);
      //temperature compensation formula: fFinalResult(25^C) = 
fFinalResult(current)/(1.0+0.02*(fTP-25.0));
      float compensationVolatge=averageVoltage/compensationCoefficient;
//temperature compensation
tdsValue=(133.42*compensationVolatge*compensationVolatge*compensationVolatge - 
255.86*compensationVolatge*compensationVolatge + 
857.39*compensationVolatge)*0.9; //convert voltage value to tds value(decrease)
      //Serial.print("voltage:");
      //Serial.print(averageVoltage,2);
      //Serial.print("V   ");
      Serial.print("          ");
      Serial.print("TDS Value:");
      Serial.print(tdsValue,0);
      Serial.println("ppm");

       lcd.setCursor(0,0);
       lcd.print("TDS:");
       lcd.print(tdsValue,0);
       delay(1000);
       Blynk.virtualWrite(V1, tdsValue);

       //TEMP CODING
       DS18B20.requestTemperatures();       // send the command to get 
temperatures
       tempC = DS18B20.getTempCByIndex(0); // read temperature in °C

       lcd.setCursor(9,0);
       lcd.print("Temp:");
       lcd.print(tempC,0);
       delay(1000);
       Blynk.virtualWrite(V2, tempC);

 lcd.clear();

   }
}
int getMedianNum(int bArray[], int iFilterLen)
{
  //TDS CODING
      int bTab[iFilterLen];
      for (byte i = 0; i<iFilterLen; i++)
      bTab[i] = bArray[i];
      int i, j, bTemp;
      for (j = 0; j < iFilterLen - 1; j++)
      {
      for (i = 0; i < iFilterLen - j - 1; i++)
          {
        if (bTab[i] > bTab[i + 1])
            {
        bTemp = bTab[i];
            bTab[i] = bTab[i + 1];
        bTab[i + 1] = bTemp;
```

```
            }
        }
        }
        if ((iFilterLen & 1) > 0)
      bTemp = bTab[(iFilterLen - 1) / 2];
        else
      bTemp = (bTab[iFilterLen / 2] + bTab[iFilterLen / 2 - 1]) / 2;
        return bTemp;
}
```