DESIGN AND FABRICATION OF IN-HOUSE SOLAR POWERED AUTOMATIC IRRIGATION SYSTEM WITH AQUAPONICS' CONCEPT

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Engineering Technology (Energy and Environment) with honors

Faculty of Civil Engineering Technology
UNIVERSITI MALAYSIA PAHANG

FEBRUARY 2022

ACKNOWLEDGEMENTS

Alhamdulillah. First and foremost, my deepest thanks and praises to Allah SWT for His showers of blessings throughout this project and giving me patience, assistance in completingthis project and thesis successfully.

I am using this opportunity to express my gratitude to everyone who supported me throughout the course of this Senior Design Project 1. I express my deep sense of gratitude to our respected and learned guides, Dr. Nadzirah Bte Mohd Mokhtar who give full support by encouraging, suggesting and guiding completing this project. I am sincerely grateful to her for sharing her truthful, invaluably constructive criticism and commitment in completing this project. Without her help, this project neither have been possible nor can be done successfully.

I express my warm thanks to the great support from Energy and Environment Lab Assistants, for their assistance cooperation in providing in providing equipment and I appreciate the assistance given Lab Assistant at workshop for their good cooperation, ideas and advice during the whole period of project in fabricating the proposed design model. I wish to extend my thanks to Faculty of Civil Engineering Technology Universiti Malaysia Pahang for the financial assistance.

Finally, I would like to thank my family members for their support and patience throughout the year, especially to my parents En. Zulkifli and Pn. Siti, where without their encouragement and support, all of this would be impossible.

ABSTRAK

Projek ini bertujuan untuk menghasilkan sistem berskala kecil untuk sistem pengairan berkuasa tenaga suria dengan berkonsepkan akuaponik. Secara amnya, sistem pengairan ialah amalan pertanian yang menggunakan jumlah air terkawal ke tanah untuk membantu dalam pengeluaran tanaman, serta menanam tumbuhan landskap dan rumput, di mana ia dikenali sebagai penyiraman. Sehubungan dengan teknologi tenaga suria, ia menjadi semakin popular di seluruh dunia bagi menggantikan sumber tenaga alternatif dengan sumber tenaga konvensional, dan kecekapan mendapatkan tenaga daripada sumber boleh diperbaharui. Bagi menghasilkan sebuah sistem pengairan yang lengkap ini, banyak pertimbangan telah diambil termasuk saiz sistem yang memainkan peranan besar untuk pengiraan kos selain ketekalan bekalan tenaga daripada sistem PV solar dan pertumbuhan tumbuhan adalah parameter penting untuk berjaya membangunkan projek ini. Saiz sistem mestilah sesuai untuk pemilik rumah. Objektif utama projek ini adalah untuk mereka bentuk dan membuat sistem pengairan berkuasa solar n-house dengan konsep akuaponik tercapai. Sistem pengairan berkuasa solar yang direka dengan integrasi konsep akuaponik berjaya mengekalkan bekalan kuasa daripada tenaga suria secara bebas selama 1 hari tanpa Tumbuhan dan ikan di dalam tangki akuarium boleh menyesuaikan diri dengan ekosistem akuaponik tanpa sebarang masalah. Juga komponen utama sistem pengairan berkuasa solar dalaman dengan konsep akuaponik. ditunjukkan dengan jelas dalam lukisan dan perinciannya dibincangkan dengan lebih lanjut dalam tesis ini.

ABSTRACT

This project was aiming to fabricate a downscale system in-house solar powered irrigation system with aquaponics' concept. Generally, irrigation system is agricultural practice of applying controlled amounts of water to land in order to aid in the production of crops, as well as to grow landscape plants and lawns, where it is known as watering. In connection with the solar energy trends, it is becoming increasingly popular around the world to replace alternative energy sources with conventional energy sources, and the efficiency of obtaining energy from renewable sources. To design this irrigation system, many considerations were taken including the size of the system which play a big role for cost calculation beside the consistency of energy supply from solar PV system and plant growth are the importance parameters to successfully develop this project. The size of the system must be suitable for homeowners. The main objective of this project which was to design and fabricate n-house solar powered irrigation system with aquaponics' concept was achieved. The fabricated solar powered irrigation system with integration of aquaponics' concept was successfully able to sustain the power supply from solar energy independently for 1 day without The plants and fish inside the aquarium tank can adapt with the aquaponics' ecosystem without any issue. Also the main components of in-house solar powered irrigation system with aquaponics' concept. are shown clearly in drawing and its detail was further discussed in this thesis.

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LIST OF SYMBOLS

A	Ampere
Ah	Amp hour
cm	Centimetre
Ca	Calcium
Fe	Iron
Ft.	Feet
K	Potassium
m	Meter
N	Nitrogen
P	Phosphorus
RM	Ringgit Malaysia
V	Voltage
W	Watt
%	Percentage

LIST OF ABBREVIATIONS

AC	Alternating Current
CAD	Computer Aided Drawing
DC	Direct Current
IOT	Internet Of Think
I_{MP}	Current at Maximum Power
PV	Photovoltaic
pHI	Scale Used to Specify the Acidity or Alkalinity
SDP1	Senior Design Project 1
SDP2	Senior Design Project 2
V_{MP}	Voltage at Maximum Power
3D	Three-dimensional

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CHAPTER 1

INTRODUCTION

1.1 Background of Project

Agricultural irrigation is the primary water user, accounting for more than 70% of all water withdrawals worldwide, and is critical to feeding the world population, accounting for 20% of total cultivated area and producing 40% of global food supply (rainfedagriculture produces 60 % with 80 %). Agriculture is undergoing a technological revolution that includes the use of sensors, renewable energy sources, and other new technologies.

Irrigation is the agricultural practise of applying controlled amounts of water to land in order to aid in the production of crops, as well as to grow landscape plants and lawns, where it is known as watering. It is also a technique of fulfilling plant or crop water requirements as an essential resource for growth. At the same time, it aids in providing plants with the nutrients required for development and growth. Irrigation has been used to cultivate plants for as long as humans have existed. Irrigation procedures are largely dependent on available water, and the water requirement is the primary factor in determining equivalent energy demand (Nasiakou et al., 2016). Irrigated agriculture is invariably a water guzzler, depriving other sectors of the limited resource. Improving water use efficiency in irrigated agriculture is thus critical for the long-term viability of agricultural production (Bwambale et al., 2022). However, irrigated agriculture will face significant challenges in the next decades as it must feed a growing population with dwindling soil and water resources due to climate change. For this reason, it will be increasingly important to use water as efficiently as possible (Antonio Rodríguez Díaz et al., 2020). Irrigation, in particular, and the adoption of improved irrigation technologies have been identified as a strategic instrument at the farm level by researchers from a variety of disciplines for enhancing irrigation and water resource sustainability (Namara et al., 2007).

In the forthcoming, solar energy is becoming increasingly popular around the world. There are, however, a variety of solar thermal and PV installed power arrangements, and the same is expected for concentrating solar power systems. Power systems are undergoing rapid transformation, prompted by the imperative to mitigate climate change but also by the dramatic cost reductions associated with renewable technologies (Tapetado et al., 2021). The global search for sustainable and environmentally friendly alternative energy sources is being driven by the depletion of conventional fuels, as well as negative environmental consequences (Nathaniel et al., 2019). Technology advancements have fomented efforts to replace alternative energy sources with conventional energy sources, and the efficiency of obtaining energy from renewable sources is constantly improving. It is feasible to use solar energy as a source of energy because it is environmentally friendly, renewable, and widely available (Hereher et al., 2020).

Aquaponics concept raise up the fish alongside plants and other species in a water-recirculating system resembling a natural ecosystem whereby fish fertilise the plants naturally, and the plants filter the fish's water. Aquaponics fish are fed a nutritionally balanced diet and swim in water sourced from municipal sources that is chemically free. Aquaponics helps to reduce overfishing (the depletion of natural fish populations below sustainable levels) and protects underwater habitats from the damage caused by some fishing methods. Aquaponics produces almost no waste, which reduces the impact of fish farming on water pollution and the potential for negative effects on the surrounding system (Kralik et al., 2022).

Based on the findings, it is found that automatic irrigation system costs for purchasing, installing and maintaining the equipment is high. Also, the reliability of irrigation system due to human error when setting up in which increased maintenance of channels and equipment to ensure it is working properly. With the integration of renewable technology, automatic systems, and enhanced of combination with aquaponics' concept for getting nutrients, this project has the potential to conserve natural resources, reduce human-time monitoring and get sufficient amount of nutrients.

1.2 Problem Statements

The existing design of irrigation system uses electricity from grid connected power supply which does not contribute to the conservation of energy resources. Energy resources are any type of fuel that is used in the modern world, whether for heating, electricity generation, or other forms of energy conversion. Three broad categories of energy resources exist are renewable, fossil, and nuclear (Novakovic et al., 2016). Renewable energy can be used to generate energy that emits no greenhouse gases, reduces some types of air pollution, increase energy diversity and reduce reliance on imported fuels. So, the use of renewable energy such as solar energy system helps on sustaining the environment. The use of solar energy for irrigation water pump is promising alternative to conventional electricity (Hartung, 2018).

Normal irrigation system requires human to monitor regularly. Irrigation systems built in the past were either prohibitively expensive or relied on non-renewable energy sources. There is imbalance in distribution of labour (Riyo, 2019). Irrigating farms requires significant human intervention, while the proposed method requires limited human intervention (Sudharshan et al., 2020).

Tap water is mineral- or chemical-rich, which can be detrimental to plants. Chlorine in tap water, which some municipalities use to destroy disease-causing microorganisms, is harmful to plants. In certain cases, the drinking water contains an excessive amount of minerals (mostly magnesium and calcium). These minerals are harmful to plants. Even filtered tap water will leave mineral and salt deposits on plants over time. Tap water contains calcium and magnesium. These accumulated salts have the potential to dehydrate the root structures. Excessive salts cause problems for plants, including stunted growth, limited new growth, dead roots, and leaf wilting. Additionally, tap water can contain nitrates from fertiliser run-off. This contributes to excess nitrogen in the soil, resulting in nutrient imbalance. So, the idea is by replacing the use of the tap water with fish tank water. Although dirty fish tank water is not good for the fish, it is high in beneficial bacteria, potassium, phosphorus, nitrogen, and trace nutrients, all of which help plants grow lush and safe (H. Dyer, 2021).

1.3 Objectives of Project

1. To design and fabricate a downscale system in-house solar powered irrigation system with aquaponics' concept.
2. To analyse the consistency of energy supply from solar panel of in-house solar powered automatic irrigation system.
3. To evaluate the plant growth and pH level of water in aquarium.

1.4 Scopes of Project

In order to achieve the objectives, the following scopes of works are proposed.

i. Designing a 3D drawing of in-house solar powered automatic irrigation system with aquaponics' concept using AutoCAD software.

ii. Selecting the best material selection based on budget, dimension and efficiency for in-house solar powered automatic irrigation system.

iii. Fabricating an in-house solar powered automatic irrigation system with combination of aquaponics' concept.

iv. Evaluating the stability of solar system for 2 weeks, the plant growth and pH level of water in aquarium throughout this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Classification of Irrigation System

Irrigation is strongly intertwined to agriculture. Irrigation has existed for as long as humans have been cultivating plants, from the ancient to the modern era. Archaeological evidence indicates that from the ancient Egyptians to the middle of the 20^{th} century, irrigation technology improved incrementally in lockstep with advancements in water technology, water transfer, and agriculture systems. The main idea behind irrigation systems is that the lawns and plants are maintained with the minimum amount of water required. The implementation of an irrigation system will help conserve water, while saving time, money, preventing weed growth and increasing the growth rate of lawns, plants and crops (Mokhtar, 2012). There are several types of irrigation system.

2.1.1 Drip Irrigation

Drip irrigation is a modern irrigation technique that aims to administer water at the roots in small amounts, in a concentrated and reluctant manner, in order to maintain the soil moisture required by the plants. Water run-off from deep percolation or evaporation is essentially non-existent with a well-designed drip irrigation system. Water use is minimised, which lowers production costs. In addition, conditions may be less conducive to the onset of diseases such as fungus. Irrigation scheduling can be precisely regulated to match crop needs, resulting in greater yield and quality (Shareef et al., 2019). Drip irrigation can aid in the efficient use of water.

Figure 2.1 Drip Irrigation System

When using drip irrigation, water is distributed in small amounts according to the daily needs of the plants and concentrated in the roots zoon, resulting in a plentiful and high-quality product. Surface irrigation techniques and sprinkler irrigation techniques, on the other hand, provide plants with enough water to meet their needs for a long time, sometimes more than a week. As a result, the plants take advantage of it excessively in the first days after irrigation, resulting in a decrease in product quantity and quality, as well as significant water and fertilizer waste (Sammis, 1980). The disadvantages of this system are drip irrigation systems have a higher initial cost than other systems. The final cost will be determined by the terrain, soil structure, crops, and water source. Pumps, pipes, tubes, emitters, and installation are generally associated with higher costs. Unexpected rain can disrupt drip systems by flooding emitters, moving pipes, or altering the salt content of the soil.

2.1.2 Sprinkler Irrigation System

Irrigation sprinklers (sometimes called water sprinklers or just sprinklers) are devices that are used to irrigate agricultural crops, lawns, landscaping, golf courses, and other areas. Sprinkler irrigation is a technique for administering water in a controlled manner, much like rainfall. Pumps, valves, pipes, and sprinklers may be used to disperse the water. Irrigation sprinklers can be used in a variety of situations, including residential, industrial, and agricultural. Water is routed to one or more central sites inside the field and distributed by overhead high-pressure sprinklers or guns in sprinkler or overhead irrigation. Because of the energy requirements for pumping and labour costs, the sprinkler irrigation system has a high initial capital cost and a high operating cost.

Figure 2.2 Sprinkler Irrigation System

2.1.3 Smart Irrigation System

In comparison to traditional irrigation systems, smart irrigation systems in Figure 2.3 provide a number of advantages. Intelligent irrigation systems can adjust watering schedules based on factors such as soil moisture and weather forecasts. This is accomplished through the use of wireless moisture sensors that interact with the smart irrigation controls and assist the system in determining whether or not the landscape requires watering. Additionally, the intelligent irrigation controller receives local meteorological data that assists it in determining when to irrigate a landscape (Sable et al., 2019). However, the disadvantage of this system is the using of IOT because it is destructive, time-consuming, labour-intensive, and requires calibration of all types of soil and also requiring routine maintenance.

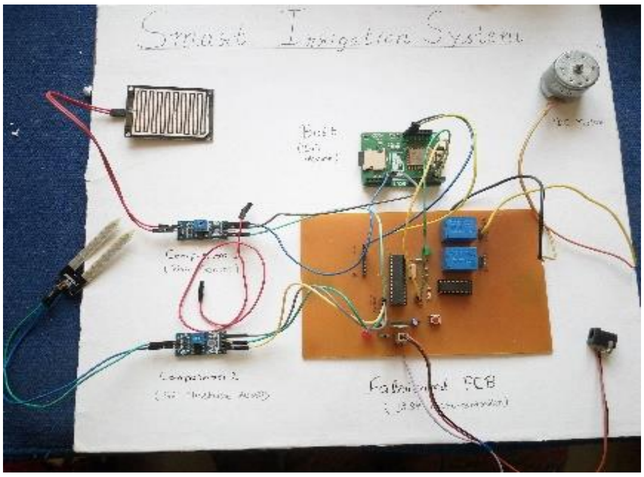

Figure 2.3 Smart Irrigation System using IOT

2.2 Selection of Material for Fabrication

2.2.1 Slotted Angle Bar

Slotted angle (sometimes referred to as slotted angle iron) is a system of reusable metal strips that is used to make shelving, frames, work benches, and equipment supports. The name stems from the usage of extended slots punched into metal at regular intervals to facilitate the assembly of structures secured with nuts and bolts, and from the longitudinal folding of metal strips to produce a right angle. This slotted angle bar is typically made from sheet metal, with the angle formed and holes punched in the metal using machine presses. Strips are typically manufactured in a range of conventional lengths, and steel versions are frequently coated or galvanised to prevent rust. Tension plates and other metal strips can also be used to reinforce the completed structure. This slotted angle bar can be cut to size (some versions include markings indicating the best spots to cut the metal) with special slotted angle cutters or shears and then secured with nuts and bolts.

Figure 2.4 Slotted Angle Bar

2.2.2 Mild Steel Hollow Square Bar

Mild steel hollow square bar is a material that is commonly required in construction and engineering.is simply cut, drilled, and welded. and offered in a 'Self Colour' Finish, which means it is bare metal with a little oiled film applied to its surface to provide some resistance to rust/corrosion, although the goods will rust quickly if left in moist settings.

Figure 2.5 Mild Steel Hollow Square Bar

2.3 Type of Pipe

Pipes are one of the most important parts made by extrusion, and it has a wide range of applications, especially in the industry. The two main reasons that make pipes attractive to the processors and markets are pipes almost unlimited range of applications and continuous production capabilities (Rosato, 1998). The materials that can be used for piping are limited by performance, installation, and maintenance needs, as well as the availability of fittings. Most thermoplastics can be used in applications that need strong joints and chemical resistance during the bonding process (Johnny De, 2015).

2.3.1 Polyvinyl Chloride (PVC)

PVC is one of the chemical industry's most valuable products. PVC is used in construction in more than half of the world's factories. PVC is a low-cost and simple-to-assemble building material. It controls 66 percent of the water distribution market in the United States. PVC pipes are rigid and strong, and are primarily used in the water, gas, and drainage systems. PVC pipes outperform traditional materials in terms of environmental impact. PVC pipes require less energy and resources to manufacture because it is a low-carbon plastic. When transported, less energy is used due to the low weight. PVC pipes are long-lasting, require little maintenance, and are easily recyclable.

Figure 2.6 White PVC Pipes

2.4 Solar Energy System

Solar Photovoltaic (PV) Technology is a method of converting solar radiation directly into electricity using semiconductors that exhibit the PV effect. Because solar energy is the most abundant source of energy, it is almost certain to become an integral part of the energy system. PV has a higher overall efficiency than other energy conversion paths from solar energy to electricity. PV is also the only renewable energy source that can be used in any location (Liu et al., 2012). Solar panels capture sunlight and convert it to direct current (DC) electricity using the PV effect. If there is no inverter in an off-grid system, the DC can be used for DC loads right away, or it can be directed to an inverter, which converts DC into alternating current (AC) suitable for conventional electric appliances. Excess energy generated by the PV panels is usually stored in batteries, which are controlled by the charge controller, for use at night when there is no sunlight for the off-grid system. The basic components of solar PV system are solar panel, mounting of solar panel, solar charger controller, battery and load.

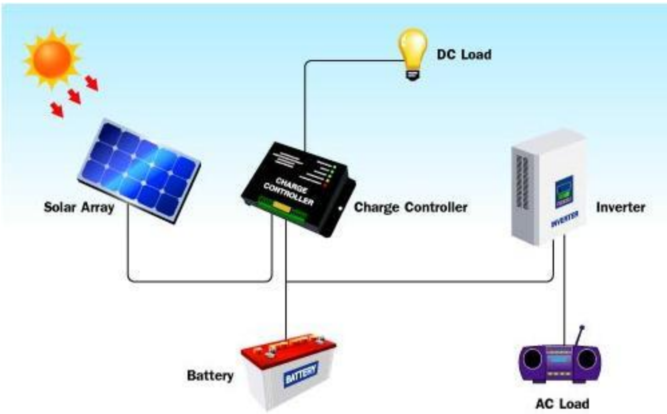

Figure 2.7 Basic Components of Solar PV System

2.5 Pumping Device

Moving fluids play an important role in a system's operation. Liquid can only move from top to bottom or from a high pressure to a low pressure system by its own power. This indicates that energy must be provided to the liquid in order to move it from a low to a higher level. Pumps are used to add the required energy to liquids. A mechanical pump is a device that transports fluid through a piping system from one point to another. Pump energy consumption is determined by the height at which the fluid is elevated, the pressure necessary at the delivery point, and the length and diameter of the pipes utilised. Liquid pumping, selection of devices is depending on several factors which are the quantity of liquid to be handled, the head against which liquid is to be transported, the properties of the liquid, the nature of power supply, and pump continuity of works (Coulson et al., 1999).

2.5.1 Submersible Pump

A submersible pump is a type of hermetically sealed pump that pushes water rather than pulls it throughout the pumping operation. Because, as the name implies, the pump is entirely submerged in the liquid to be pumped, it can operate in this fashion. This enables the pump to be dropped into a deep pit for pumping purposes without encountering any issues. Pumps that are submersible are utilised in a wide range of industrial and commercial applications.

2.6 Aquaponics' System

Aquaponics is a combination of the words "aquaculture" and "hydroponics." It refers to closed-loop systems that combine fish processing and soilless plant cultivation. Aquaponics, which is based on the ancient principle of integrated farming, recirculates nutrient-rich effluent water from aquaculture for use by plants that absorb the nutrients. Bacterial cultures make nutrients accessible to plants in this biological phase, and the water is thus washed for reuse in aquaculture tanks (Rakocy, 2012). Aquaponics is a new method of local food production that is gaining popularity around the world. Aquaponics systems have the potential to be designed for a variety of applications ranging from small, private installations to large commercial enterprises. Utilization of nutrients released in aquaculture effluents results in a reduction in the use of fertilisers for plant growth. There is usually a need to supplement the aquaponics method with trace minerals such as calcium (Ca), potassium (K), and iron (Fe), depending on the crops and growth stage, but overall there is a significant reduction in fertiliser usage.

Aquaponics is a sustainable food production technology that integrates aquaculture (fish farming) and hydroponics in a symbiotic relationship. When effluents are used in aquaculture, they accumulate in the water, increasing the toxicity to the fish. This water has resulted in the development of a hydroponic system in which by products of aquaculture are filtered out by plants as necessary nutrients, and the cleansed water is then recirculated to the animals. Aquaponics is a misnomer for aquaculture and hydroponics. Aquaponics' systems come in a variety of sizes, ranging from small indoor or outdoor units to big commercial units, all of which utilise the same technology as illustrated in Fig. 1. Although fresh water systems are more common, salt water systems are possible depending on the aquatic animal and plant species. Aquaponics is divided into two components: aquaculture, which involves the breeding of aquatic animals, and hydroponics, which involves the cultivation of plants (Mohamad, 2013). Figure 2.8 illustrates on aquaponics working system and concept. Aquaponics, the practise of combining fish farming and hydroponic gardening, has enormous potential for sustainable food production. Despite increased research and investment in commercial-scale systems, aquaponics is not yet a profitable sector, with the majority of companies reporting losses. Aquaponics' produce is believed to be more valuable to both the user and the community (Greenfeld et al., 2020).

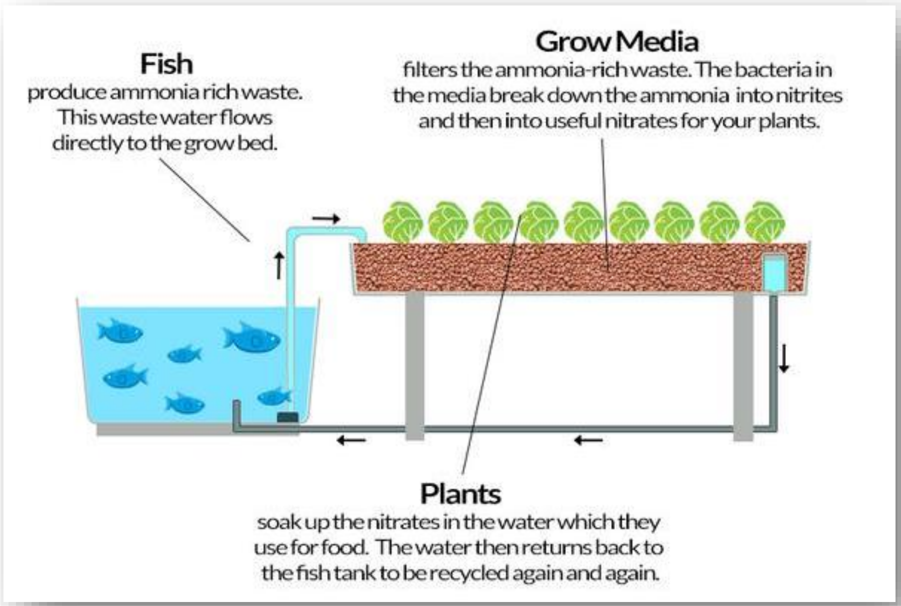

Figure 2.8 An aquaponics working system

Aquaponics is now considered a modern and evolving industry with a position in the wider, global agricultural production context, and there are many variants of the technology of combining fish culture with aquatic plant culture that are grouped under the aquaponics banner or name (Kyaw, Thu Ya, Ng, 2017). Aquaponics aims to combine aquaculture animal production with hydroponic plant production by employing a variety of methods to share water and nutrient resources among the major production components in order to produce commercially viable fish and plant products.

2.6.1 Fish

Guppy fish in aquaponics has the advantage of allowing to grow herbs and vegetables while also raising vibrant, hardy fish. A popular species of live-bearing freshwater aquarium fish is the guppy fish, also known as the rainbow fish or million fish. Guppies prefer a temperature range of 72 to 78 degrees Fahrenheit. Temperature fluctuations are not a problem for it. As a result, keeping the pH between 6.7 and 8.5 is crucial. Some aquaponics enthusiasts prefer a guppy-only because guppies mix well with other fish species since that fishes are peaceful and easy-going community fish. Guppies are a low-maintenance fish that are ideal for beginners. Guppies are omnivores who are fed commercially available feeds such as micro pellets, which contain more nutrients than flakes and are better for them. In the wild, the average guppy fish lives for only two years, but in an aquaponics system, guppy can live for up to five years. Because of their small size, these fish reproduce quickly and are easy prey for many other fish. Thus, Guppy aquaponics is a great way to combine hydroponics and aquaculture to create a long-term source of food and income. Guppies are a popular aquaponics option because guppies are bright, hardy fish that get along with mollies, platys, and zebrafish.

Figure 2.9 Guppies fish

2.6.2 Plant

In a small system, there will be fewer fish and less waste, which will result in lower nutrient concentrations. Larger systems contain more fish, produce more waste, and contain higher concentrations of nutrients. This distinction has an impact on the types of plants that can be grown in the system. Plants that require low nutritional inputs, such as greens and herbs, benefit from a small, nutrient-dense system. Small aquaponics systems can grow a variety of plants such as lettuce, kale, spinach, Swiss chard, arugula, mint, chives, basil, watercress, pak choi, wheatgrass and radish sprouts. Water spinach is a nutritious food that widely cultivated.

2.7 Integration between Solar Energy System and Aquaponics' System

Today's primary energy sources, such as oil, gas, and nuclear power, are more expensive than ever. Apart from the price, the amount of non-renewable resources is diminishing and approaching depletion, while global demand continues to rise. If this situation continues, it has the potential to create havoc throughout the world. Additionally, burning fossil fuels produces greenhouse gases, which contribute to the acceleration of global warming. Malaysia derives the majority of its energy from oil. Due to the fact that the world is consuming energy sources, precautionary measures to protect the environment must be taken. Renewable energy is an excellent substitute for conventional energy sources. Malaysia is well-suited for solar energy production due to its proximity to the equator, which receives average 12 hours of sunlight per day and night throughout the year. Thus, because the project (Mohamad, 2013) is located in Malaysia, the solar panel is the ideal green energy source for powering aquaponics solar powered control pump.

CHAPTER 3

METHODOLOGY

3.1 Fabrication Process

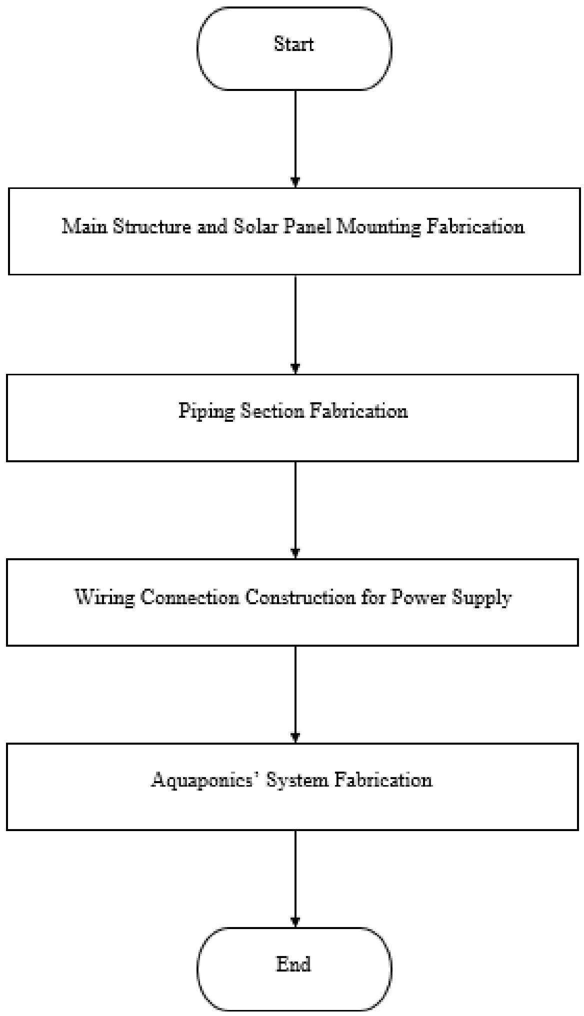

Figure 3.1 Flow of Fabrication Process

After the completion of the design using AutoCAD's software, the fabrication process can be started. The fabrication process started with the fabrication of the main structure and solar panel mounting which need to be fabricated parts by parts using chosen materials which are mild steel hollow square bar and slotted angle bars before the parts being combined and fixed into irrigation system. After the fabrication of the main structure and solar panel mounting completed, the piping section were fabricated based on sketched design. The pipes are being drilled with a diameter 1.5 inches for 47 holes whereby the plants will be located. Next, piping fitting at which the pump, tank and pipe were fitted to the system. The piping need to be installed firmly to ensure that there were no any leakages. Lastly, when all of the fabrication process has completed, the wiring connection of system fabrication and aquaponics' system need to be done to make the system running successfully.

3.2 Fabrication of In-house Solar Powered Automatic Irrigation System with Aquaponics' Concept

Figure 3.2 Complete System of In-house Solar Powered Automatic Irrigation System with Aquaponics' Concept

Figure 3.2 showed the complete full system of the in-house solar powered automatic irrigation system with aquaponics' concept which has been fabricated. There were several main components of the system that were important and had been fabricated to complete the whole system successfully. The in-house solar powered automatic irrigation system with aquaponics' concept consist of the main structure, solar panel mounting, piping section, wiring connection construction and aquaponics' set up. The in-house solar powered automatic irrigation system with aquaponics' concept then were tested and ran for analysis evaluation.

3.2.1 Main Structure

Main structure was fabricated as the placed to hold the complete system. The structure holds the piping section, aquaponics' system and also electrical system. The main structure was made up from 1-inch x 1-inch slotted angle bar. The structure also was coated with black paint to prevent the bar from corrosion. The platform also was attached with the wheels to easier the transportation purpose. The main structure need to be strong and manage to hold the heavy weight of the irrigation system also the weight of aquarium tank which contains 40 litre of water. The slotted angle need to be bolted firmly to ensure that the main structure stays strong. The fabrication of the base was followed the arrangement of the system and the chassis need to be tough enough to hold the system weight and pressure.

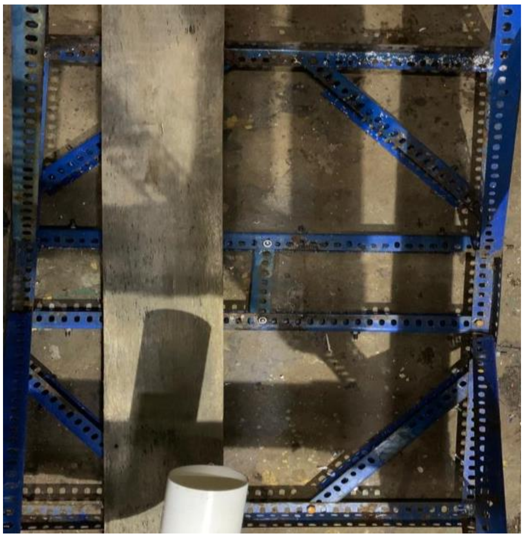

Figure 3.3 Configuration of The Base for Main Structure

During the fabrication, cutting process involved. The cut-off machine was used to cut the slotted angle bar with desired length. As for the safety precaution, the fabricator need to wear sturdy footwear with protective clothing at all times in working areas and need to ensure all the adjustments to machine are secure before making a cut. In addition, the fabricator need to make sure the table and work area are clear of all tools and off-cut material, inspect the cut off wheel for chips and cracks.

Figure 3.4 Cutting Process

Figure 3.5 Completed Main Structure after fabrication

After fabrication of the main structure was finished, painting process is required to prevent the slotted angle bar from corrosion and finishing purpose. Oil-based paint was used which is high gloss black in colour.

Figure 3.6 Painting Process

3.2.2 Solar Panel Mounting

The mounting of solar panel was designed to hold a 50W type of solar panel. The dimension of the solar panel is 680mm of length, 25mm of width and 540mm of height. The idea to design the mounting was standalone unit since the 50W solar panel is quite heavy for the main structure to hold it. Moreover, standalone mounting is easy-access to locate the solar panel anywhere. So, the 1-inch x 1-inch of mild steel hollow square bar was used to construct the solar panel mounting is 5 ft. and it can be adjusted into several heights for better sun light reception.

Figure 3.7 Fabrication of Solar Mounting

In order to join the mild steel hollow square bar together, welding process that shows in. Welding is a fabrication method in which two or more components are fused together using heat, pressure, or a combination of the two, establishing a join when the components cool. Welding is typically used on metals and thermoplastics, but it can be used on wood as well. A welded joint that has been completed may be referred to as a weldment.

Figure 3.8 Welding Process

After the welding process is completed, the 50W of solar panel can attached on that mounting perfectly. Solar panels should ideally face true south to generate the greatest power. South-west and south-east facing roofs are likewise considered highly efficient, however east or west facing roofs lose roughly 15% of their efficiency when compared to a south facing roof.

Figure 3.9 Complete Solar Mounting with Attached Solar Panel

The specification of solar panel that was used is the maximum power of 50 Watt. The weight is around 3.5 kg. The optimum operating power (V_{mp}) is 18.6V while the optimum operating current (I_{mp}) is 2.69A. Then, the operating temperature for this solar panel is -40˚C to +90˚C

$$Total\ PV\ panel\ energy\ needed = Total\ appliance\ u/day)\ x\ Energy\ lost \quad 3.1$$

$$Total\ WP\ of\ PV\ panel\ capacity = Total\ appliance\ use/3.4 \quad 3.2$$

$$Number\ of\ PV\ panels\ needed = Total\ WP\ of\ PV\ panel\ capacity/30W \quad 3.3$$

3.3 Piping Section

While constructing the pipe section, the measuring process and drilling process are occurred. Figure shows the measuring process in order to make markings for drilling the hole in which that holes are the place where the plants will be placed. The size of each hole is 2 inch with a total number of 47 holes. Then, Figure shows the completed pipe section with holes and the pipes itself are attached with main structure of this system.

Figure 3.10 Measuring Process Before Drilling The Holes

The white PVC pipe with diameter of 3 inch was used to complete the piping section. The distance between holes is 6.5 inch whereby it is the ideal distance for planting the water spinach to get nutrient equally. So, the total length of this system is 3.8 feet, 5.5 feet of height and 2.5 feet.

Figure 3.11 Completed Piping Section on Main Structure

3.4 Wiring Connection Construction

After the main structure was completely fabricated, the connection of system need to fabricate in order operate the system. The 50W solar panel was connected to the solar charger controller and then the solar charger controller must to be connected to the batteries and loads which is the pump. The timer relay was installed in order to set the operation time of the pump in a day.

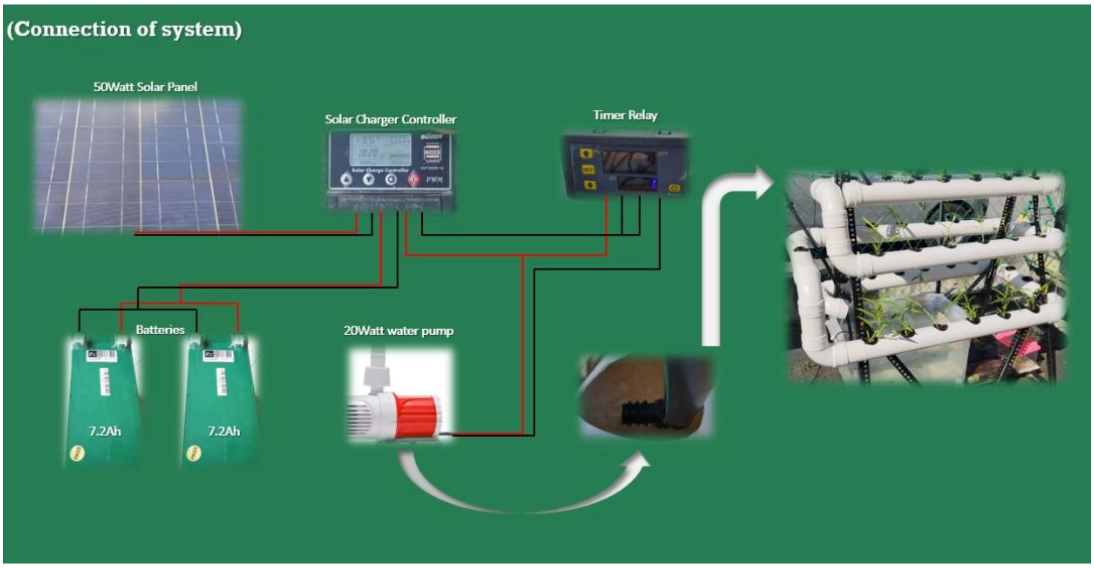

Figure 3.12 Connection of System

3.4.1 Solar Charger Controller

The solar charger controller has been set from 8 a.m. until 6 p.m. for the system to charge the batteries. So, battery was charging from the morning and ended at 6 p.m. Based on the loads capacity, the pump was able to operate within that time without any issues even though on rainy seasons.

Figure 3.13 Solar Charger Controller

$$\textit{Solar charge controller rating} = \textit{Total short circuit current of PV array} \times 1.3 \tag{3.4}$$

3.4.2 Timer Relay

Timer relay is a device that being used in order to cut off the current supply to the loads based on settings. For this project, the setting of timer relay was being set 3 minutes of running time and 15 minutes for stopping time. This setting works interval starting from 8 a.m. to 6 p.m.

Figure 3.14 Timer Relay

3.4.3 Battery

Two of 7.2ah sealed lead acid battery were used in this system and connected in series. So, the total value of voltage become doubled. This is to ensure the pump gets enough electric supply to operate in a day.

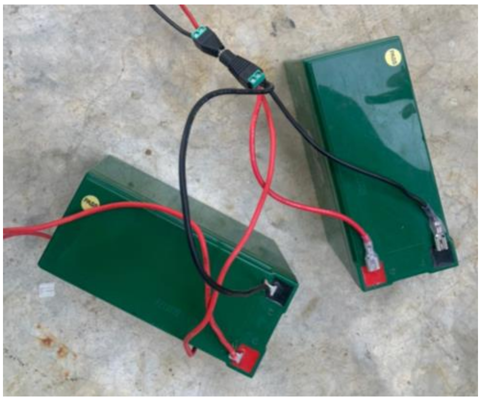

Figure 3.15 7.2ah Sealed Lead Acid Battery

$$Battery\ Capacity\ (Ah) = \frac{Total\ Watt - hours\ per\ day\ used\ by\ appliances\ \times Days\ of\ autonomy}{(0.85 \times 0.6 \times nominal\ battery\ voltage)} \quad 3.5$$

3.4.4 Pump

The 20W of submersible was used in this project which suitable to irrigate the plants through all level of pipe. All the plants receive water supply from the system with adequate amount of water.

Figure 3.16 20W of Submersible Pump

3.5 Aquaponics' Set Up

After all the connection system was completed, the aquarium tank was filled with water around 40 litres. Then, the guppy fishes were placed inside the tank. So, it will produce ammonia from excretion and the bacteria inside the water will converts the ammonia into nitrates as nutrient to the plants. Maintenance of the water is required as the water turns into green due to algae's growth. The recommended period of maintenance is 2 times in a month.

Figure 3.17 Guppy Fishes Inside Aquarium Tank

3.6 Working Principle of System

Based on the flowchart, the system starts when solar panel absorb sunlight for charging purpose and store the transformed energy into the batteries. Thus, the solar charger controller will distribute the current to the timer relay and pump. The pump will run 3 minutes after rest from 15 minutes. There will be no electricity supply if the battery fails to store the electric due to heavy rainy season.

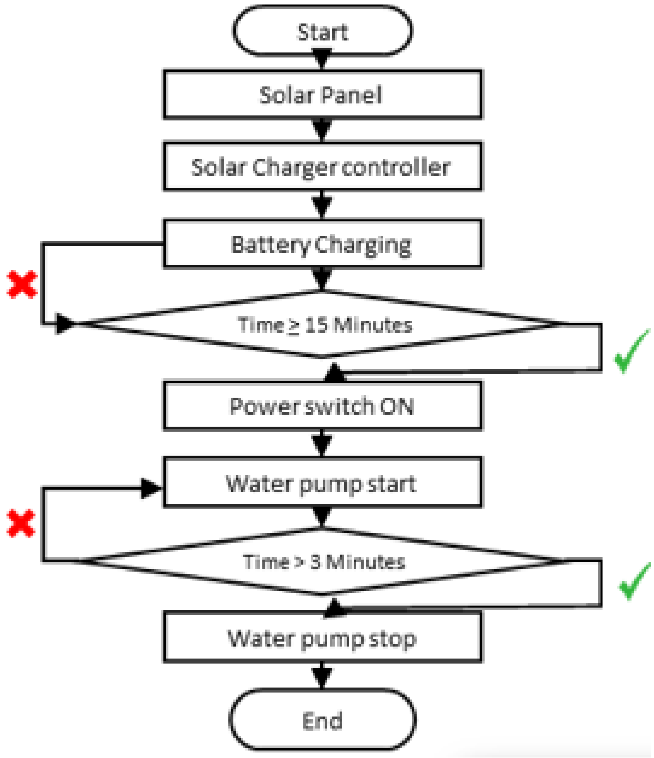

Figure 3.18 Working Principles of System

3.7 Evaluation Method

Evaluation method is to monitor the consistency of energy supply from solar panel of in-house solar powered automatic irrigation system and evaluate the plant growth and pH level of water in aquarium. There were 3 conducted method in this evaluation.

3.7.1 Height of Plant

Height of plants was measured using ruler in centimeter. The height of all plants were recorded for 2 weeks. Only 1 times in a day to collect data for the plants' height. This height represents the growth rate of the plants

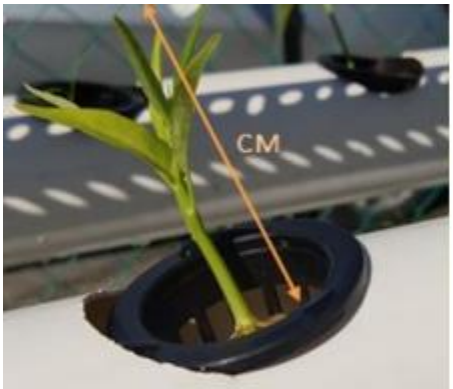

Figure 3.19 Height of Plant To Measure

3.7.2 Battery Voltage

To ensure the consistency of electric supply for this system, the reading of voltage is need to be measured by using multi meter. This multi meter will displayed the reading of voltage after negative and positive pin are contacted to the system. The data of battery voltage need to be taken at 2 hours during operation time in a day

Figure 3.20 Multi meter

3.7.3 pH level of Aquarium Water

The pH level of water in aquarium was tested using pH meter. This meter will have displayed the value of pH on a mini screen. The data of pH need to be taken also at 2 hours during operation time in a day. The pH meter was dipped in water and within a few seconds, the data can be collected.

Figure 3.21 pH meter

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Outcome of Fabrication

The concept of a 'In-House Solar Powered Automatic Irrigation System with Aquaponics' was realized effectively. The system must run for 14 days in order to monitor and analyze plant height development, battery capacity variations over 14 days, and changes in the pH value of the aquarium water tank. There are three levels of height for the plant to grow in this project; the highest level of the system has 11 pots, the middle level contains 14 pots, and the lower level contains 15 pots. All pots were connected using white PVC pipes and a pump to transfer water from the aquarium tank to the upper level, where it will flow through the middle level and eventually back into the aquarium tank on the lower level. The configuration of solar system, and connecting the wiring, this project successfully developed a "In-house Solar Powered Automatic Irrigation System with Aquaponics' Concept." The system can function autonomously without relying on grid electricity. The batteries are connected to the solar charger controller, which is also connected to a 50W solar panel, which charges the batteries using solar energy. The battery serves as the power supply for the pump, enabling the system to operate. The pump will automatically start at 8:00 a.m. and cease at 6:00 p.m. During that period, the pump will run for three minutes and then rest for around fifteen minutes.

Figure 4.1 Completed System of In-house Solar Powered Automatic Irrigation System

4.2 Evaluation of Analysis

4.2.1 Analysis Plants Height Against

The result of plants height in cm against the different level shown in Figure and Table 1. The lower level seems the best location because the plants are growing better that other level. This is because the water level of each level are not the same. Lower level contains the most of amount water among others. So, the higher the amount of water, the rapid the plants can grow.

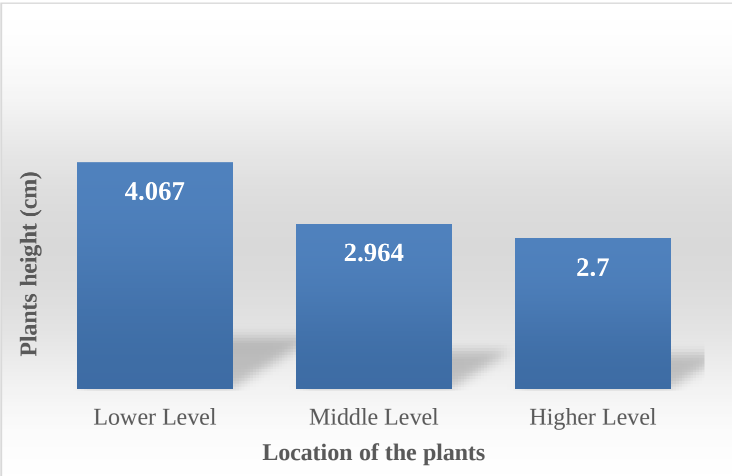

Figure 4.2 Plants height (cm) against different level of plants's location data

Plant growth is the irreversible increase in the size of a cell, organ, or plant as a whole. It entails both cell division and expansion. Plant growth can be quantified in terms of increased length or height, stem diameter, tissue volume, cell number, fresh and dried weight, leaf area and weight, and so on. Plant growth analysis is necessary to explain discrepancies in plant development, whether between species growing in the same environment or within a species growing in various settings (Pandey et al., 2017).

4.2.2 Analysis of Battery Voltage against Days

Based on the result, the solar energy system for this project can supply the electricity to the pump in a day even though there was rainy season on day 4. The value of voltage which is 11.9V is still consider good enough to activate the pump on the next day. However, for ideal condition, the reading of voltage should be greater than 12.6 V and less than 14.0 V. As a result of too high a charge voltage excessive current will flow into the battery, after the battery has reached full charge. This will cause decomposition of the water in the electrolyte and premature aging.

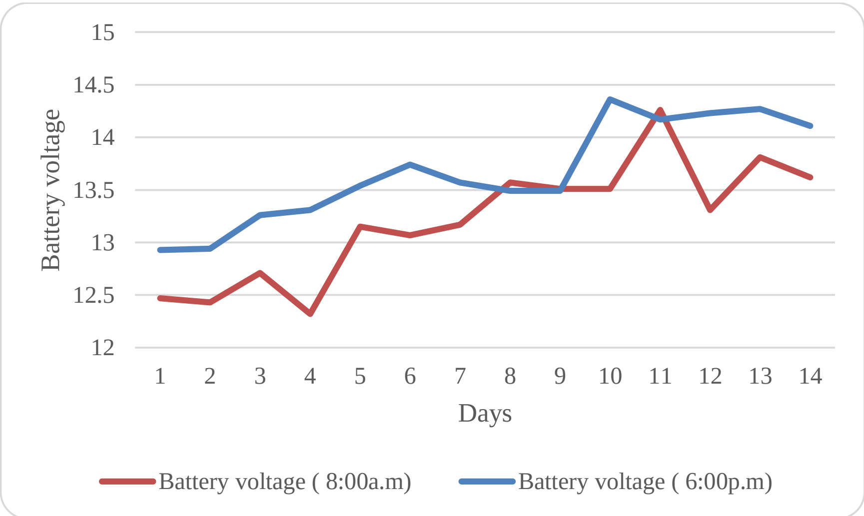

Figure 4.3 Battery voltage (V) against days' data

4.2.3 Analysis of pH Level Water in Aquarium Tank

The purpose of testing the pH of an aquarium tank is to evaluate the tank's condition as a fish habitat. Based on the result, guppy fishes still can live in the aquaponics' system because the range of pH is still considerable. The highest value resulted at 8.7 and the lowest value resulted at 6.8. In reality, the guppy fishes can survive inside the aquarium tank as well hatching

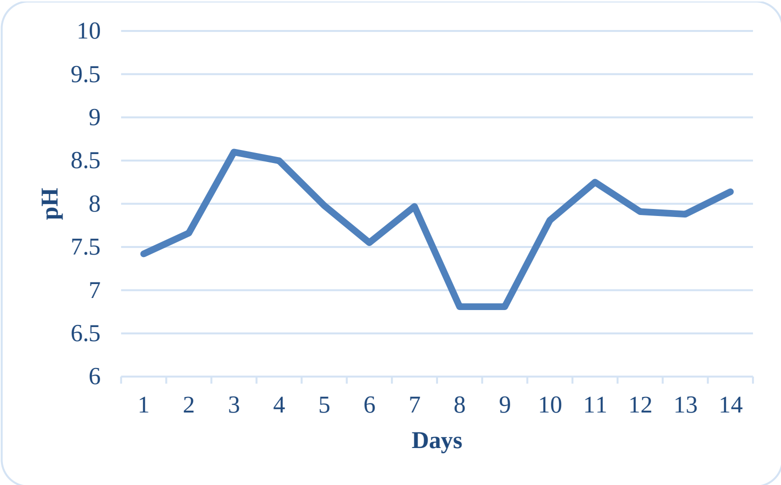

Figure 4.4 pH in fish tank against days' data

When pH levels fall outside of this range (up or down), animal systems are stressed, and hatching and survival rates suffer. The higher the mortality rates, the further a value is from the ideal pH range. Changes in pH have a greater impact on more sensitive species. Extreme pH values enhance the solubility of elements and compounds, making harmful chemicals more "mobile" and raising the risk of absorption by aquatic life, in addition to biological impacts. The ideal pH for fish is between 6.5 and 9.0.

4.3 Project Planning

4.3.1 Gantt Chart for SDP1

ACTIVITES	WEEK 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Briefing Session & Group Recruitment	■													
Title Briefing by Supervisor & Submission form A1		■												
Project Introduction & Task Distribution			■											
Draft of Introduction				■										
Literature Review Survey				■	■									
Completion of Design & Submission form A2					■	■	■	■						
Preparation Slide Presentation for proposal defend							■	■	■	■				
Material Listing and Selection									■	■				
Preparation of proposal first draft										■				
Submission of Proposal to Supervisor											■			
Approval of Proposal by SV & Submission form A3												■		
Presentation of Proposal Defend SDP1												■		
Improvise of proposal													■	
Submission Final Proposal														■

Figure 4.5 Project Timeline Senior Design 1

4.3.2 Gantt Chart for SDP2

ACTIVITES	WEEK 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Fabrication of irrigation system structure	■	■	■											
Installation of fish tank		■												
Do piping for water supply			■	■										
Fabrication of solar mounting				■										
Install all the components (pump, battery and etc.)				■	■									
Do wiring connection					■									
Test run the system						■	■							
Put the plants in place and fish inside aquarium							■							
Modify and improvise process *if required*							■	■	■					
System successfully built									■					
Evaluate the plant growth for several weeks									■	■				
Analysis the efficiency of energy usage										■	■			
Literature review	■	■	■	■	■	■	■	■	■	■	■	■	■	
Submission of thesis report														■

Figure 4.6 Project Timeline Senior Design 2

4.4 Cost Analysis

In this project, our target is to design and develop an in-house solar powered automatic irrigation system with aquaponics' concept which affordable for the household users nowadays. The listing of items, quantity, price per unit and the total price of all items is show in the Table 1. Even though the funds given by the Faculty of Civil Engineering Technology is RM400 only, our project will be supported under lecturer's grant.

Table 1: Listing of Materials Cost

NO.	ITEM / MATERIAL	DETAILS	PRICE PER UNIT	UNIT	TOTAL
1	Solar Panel (Monocrystalline)	50W	RM270	1	RM270
2	Battery (Lead Acid)	7.2Ah	RM38	2	RM76
3	Pump (Irrigation)	20W	RM30	1	RM30
4	Solar Charge Controller	10A	RM17.58	1	RM17.58
5	Timer DC)	Size: 70 x 40 x 18mm	RM11.61	1	RM11.61
6	Container	254mmx226mmx177mm	RM11.00	1	RM 11.10
7	Hose	22mm	RM6.50	1	RM 6.50
8	Aquarium Tank	W700 x L500 x H400mm	RM59.90	1	RM 59.90
9	Wire	10m	RM34.1	1	RM 34.1
10	PVC pipe	3 inch ,5.8 meter	RM42.00	2	RM84.00
11	PVC bend	80mm	RM4.95	15	RM74.25
12	PVC end cap	80mm	RM3.35	1	RM3.35
13	Wood	120cm	RM12.50	2	RM30
14	Slotted Angle Bar	5ft.	RM7.00	3	RM21.00
15	Mild steel hollow	1 inch x 1 inch, 3 FT.	RM10	1	RM10.00
					RM 739.39

4.5 Ethical Consideration

As to the start of the fabrication process, the safety precaution must be practice to avoid any injuries especially in workshop. At our workplace, safety precautions such as wearing safety boots, jackets, goggles, and masks while handling tools and machines must be observed. The jacket will shield us from the chips, dust, and any fire sparks generated during the metal sheet cutting process. The chips generated during the cutting process are quite sharp and heated, posing a risk of injury. Our feet are protected by the safety boots from being struck by heavy materials, which could result in fractures and bleeding. Every type of machine operation has its own preferences must be conducted follow by the correct procedure and tools to avoid accident happen in the workshop. Aside from that, teaching fabricators from the workshop play an important role in providing guidance during the fabrication process, and any incident that occurs should be immediately reported to the workshop's in charge to minimise the risk to students. To ensure that the project could be completed in the allotted time, the tasks were distributed evenly among the group members. To ensure that the project could be completed in the allotted time, the tasks were distributed evenly among the group members. Good teamwork and mutual respect among team members, on the other hand, were implemented and valued in the team. Based on our skills and knowledge, each of us has a major task and contribution in various parts such as fabricating, analysing, and evaluating. The most challenging tasks attended in this project are the analysis of the consistency and the evaluation of the plant growth and pH level in aquarium due to rainy season in Pahang. So, the collected data need to take the average value for our results.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The main objective of this project was to design and fabricate the in-house solar powered automatic irrigation system with aquaponics' concept was achieved. The fabricated solar powered irrigation system was successfully uses electricity from solar panel system power supply. This design of the irrigation system was aiming for in-house purpose and its dimension and sizing were not suitable for larger scale purposes such as industrial. This project only cost below than seven hundred ringgit Malaysia compared to the industry irrigation system which was very expensive. The solar powered irrigation system also was not complicated to fabricate because it can be fabricating by using normal machining tools such as welding machine, cutter machine, welding machine, hand drill and grinder.

In addition, this solar powered irrigation system also can be dissembled by parts. This advantage helps in moving this system from one location to another location a lot easier and easy to do maintenance. For overall system operation, the irrigation system works fully independent electricity power supply from solar system to activate the pump. The pump for this irrigation system operates automatically by installing a timer relay with interval in 3 minutes and rest for 15 minutes. The working cycle of this pump is from 8 a.m. until 6 p.m. The wiring connection has been tested and checked to ensure the system is running properly. The main structure also can handle all of the system weight steadily without any issues.

Furthermore, the integration between solar energy system and aquaponics' system were chosen in designing this irrigation system due to its advantage by using renewable technologies and it has been proved that nutrients from aquaponics' system can support the plant growth successfully based on the result obtained. As for conclusion, this project is able to build a one-stop system that will pleasant to the consumer whereby homeowners can do planting of plants without using electricity to power up the pump, saving time in monitoring the plant and worry-free of insufficient amount of nutrients toward plant.

5.2 Recommendation

Here are some of recommendation to improve in this project:

i. Install shade at the top part of this project due to during sunny day might cause the plants dried (yellowish).
ii. The water level configuration for this project need to recalibrate in order to solve the imbalance water level for each level.
iii. Add-on aquarium plants aquarium tank to reduce the growth of algae that can preserve the clarity of the water from being green quickly.
iv. Carry out analysis on NPK, the proportion of three plant nutrients in order: Nitrogen(N), Phosphorus (P) and Potassium (K)of the water would be more interesting in doing research for this project.

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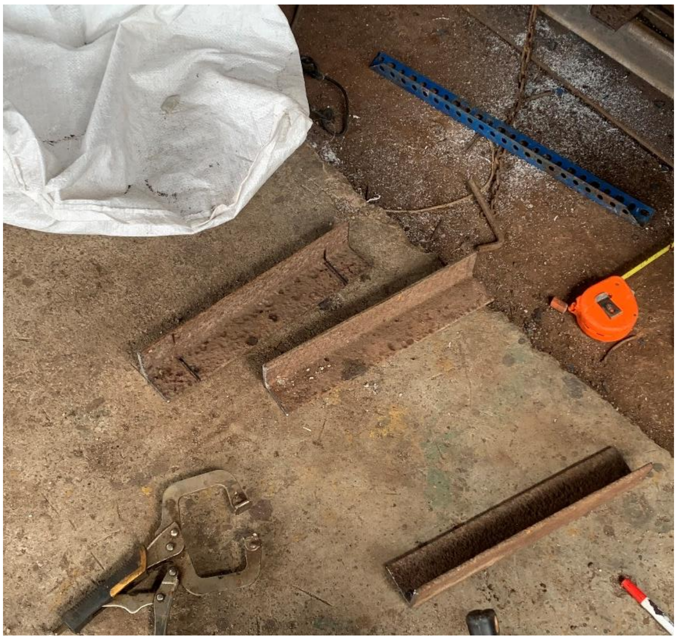
APPENDICES

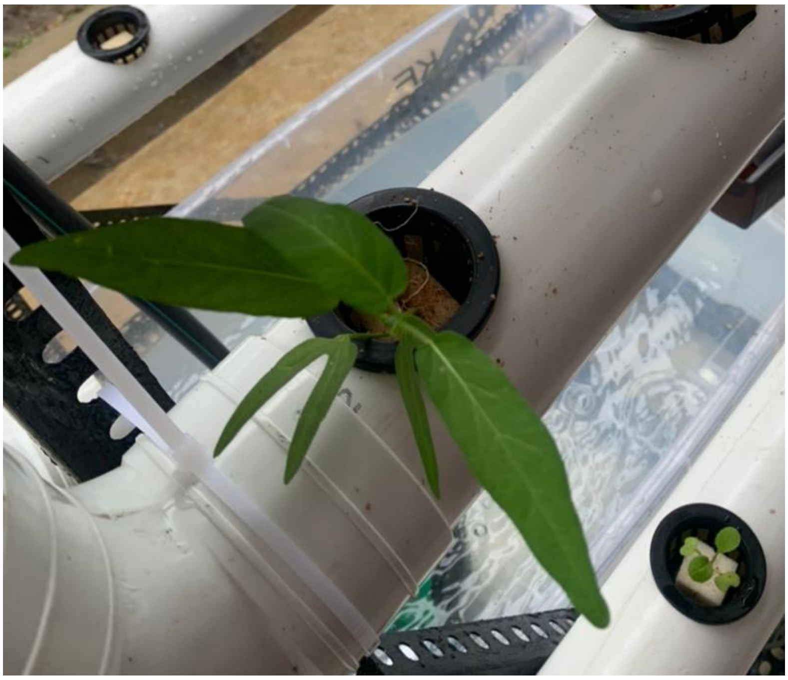
Appendix A:

Title: MAIN STRUCTURE, SOLAR PANEL MOUNTING & PIPING MATERIALS



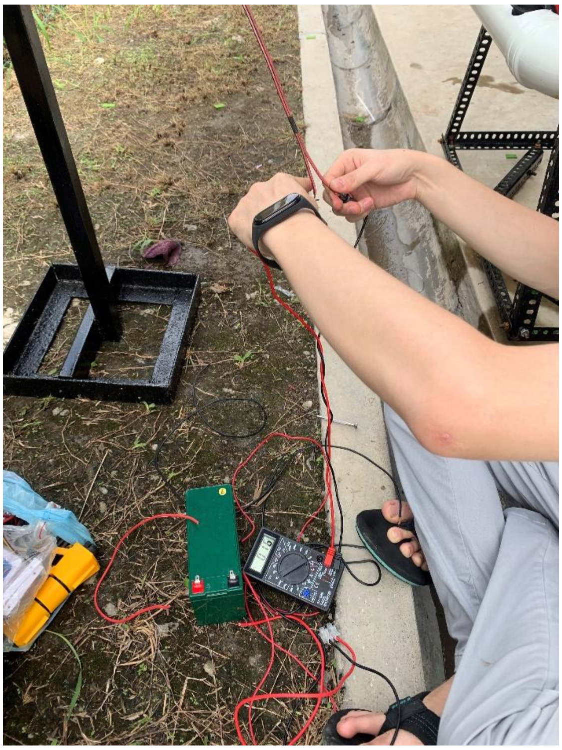
Appendix B:

Title: PLANTING PROCESS



Appendix C:

Title: CONNECTION OF WIRING PROCESS



Appendix D:

Title: SITE-VISIT FROM LECTURER