Faculty of Electrical Technology and Engineering

THE DEVELOPMENT OF A HYBRID MICRO-HYDRO AND SOLAR PV GENERATION IN A RAINWATER HARVESTING SYSTEM

MUHAMMAD ZAFRAN BIN MOHD SALLEH

Bachelor of Electrical Engineering Technology with Honours

2023

THE DEVELOPMENT OF A HYBRID MICRO-HYDRO AND SOLAR PV GENERATION IN A RAINWATER HARVESTING SYSTEM

MUHAMMAD ZAFRAN BIN MOHD SALLEH

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

Faculty of Electrical Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI KEJUTERAAN ELEKTRIK DAN ELEKTRONIK

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : The Development Of A Hybrid Micro-Hydro And Solar PV Generation In A Rainwater Harvesting System

Sesi Pengajian: 2023/2024

Saya Muhammad Zafran bin Mohd Salleh mengaku membenarkan laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

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

☐	**SULIT***	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
☐	**TERHAD***	(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☑	**TIDAK TERHAD**	

Disahkan oleh:

ZAFRAN

(TANDATANGAN PENULIS)

(COP DAN TANDATANGAN PENYELIA)

Alamat Tetap:

No 1 Lorong 1 Jalan Mj 18
Taman Merdeka Jaya,
Batu Berendam, 75350, Melaka

MOHAMAD NA'IM BIN MOHD NASIR
Pensyarah Kanan
Fakulti Teknologi dan Kejuruteraan Elektrik
Universiti Teknikal Malaysia Melaka

Tarikh: 15 Februari 2024

Tarikh: 15 Februari 2024

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

DECLARATION

I declare that this project report entitled The Development Of A Hybrid Micro-Hydro And Solar Pv Generation In A Rainwater Harvesting System is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ZAFRAN

Student Name : MUHAMMAD ZAFRAN BIN MOHD SALLEH

Date : 28/12/2023

APPROVAL

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

Signature : ....

Supervisor Name : MOHAMAD NA'IM BIN MOHD NASIR

Date : 05 /02/2024

Signature : ....

Co-Supervisor : ....

Name (if any)

Date : ....

DEDICATION

The Development of a Hybrid Micro-Hydro and Solar PV Generation in a Rainwater Harvesting System, my individual final year project, is devoted to the search for environmentally friendly energy sources. This project is the result of years of hard work and a steadfast dedication to using nature's resources to create a more sustainable, eco-friendly future. I want to express my deepest appreciation to my family for their unwavering encouragement and support during this trip. I express my gratitude to my supervisors for their crucial assistance and insights that have impacted my thinking. This dedication is a testament to your unwavering effort, which has been put into the numerous hours of research and experimentation.

ABSTRACT

In an era of increasingly rapid development and new technological surprises, the rainwater harvesting system represents one of the government-introduced systems that is experiencing accelerated growth in our country. This project, which is for a small-scale rainwater harvesting system, still needs to be applied, especially for producing renewable energy and other uses of rainwater. In order to overcome the problem, the production of an efficient rainwater harvesting system is highly encouraged as a backup and to support daily water use as well as other uses such as irrigation and flushing tanks. Therefore, this project aims to produce a hybrid micro-hydro and solar PV generation project in a rainwater harvesting system that is worthwhile, user-friendly, more extensive in rainwater use, and does not damage the environment. A number of experimental series have been undertaken to investigate the performances of the system. In conclusion, the experimental results demonstrate that the hybrid system outperforms other alternatives significantly.

ABSTRAK

Dalam era pembangunan yang semakin pesat dan kejutan teknologi baharu, sistem penuaian air hujan mewakili salah satu sistem yang diperkenalkan kerajaan yang mengalami pertumbuhan pesat di negara kita. Projek ini iaitu untuk sistem penuaian air hujan berskala kecil masih perlu diaplikasikan terutama untuk menghasilkan tenaga boleh diperbaharui dan kegunaan lain air hujan. Bagi mengatasi masalah tersebut, penghasilan sistem penuaian air hujan yang cekap adalah amat digalakkan sebagai sandaran dan menyokong penggunaan air harian serta kegunaan lain seperti tangki pengairan dan simbah. Oleh itu, projek ini bertujuan untuk menghasilkan projek penjanaan mikrohidro dan solar hibrid dalam sistem penuaian air hujan yang berbaloi, mesra pengguna, lebih meluas dalam penggunaan air hujan, dan tidak merosakkan alam sekitar. Beberapa siri eksperimen telah dijalankan untuk menyiasat prestasi sistem. Kesimpulannya, keputusan eksperimen menunjukkan bahawa sistem hibrid mengatasi alternatif lain dengan ketara.

ACKNOWLEDGEMENTS

I would like to begin by extending my sincere appreciation to my supervisor for their invaluable mentorship, insightful advice, and unwavering patience during this endeavour.

Additionally, Universiti Teknikal Malaysia Melaka (UTeM) deserves credit for the financial assistance that enabled me to complete the undertaking. Not neglecting the willingness of my colleague to contribute his thoughts and ideas to the undertaking.

The affection and prayers of my parents and other family members throughout the time that I was studying have my deepest gratitude. Additionally, my closest friend deserves recognition for providing encouragement and understanding.

Ultimately, I would like to extend my gratitude to the entire faculty, staff, classmates, and fellow professionals for their assistance and cooperation, in addition to any other individuals who may not be specifically mentioned.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

V	-	Voltage
A	-	Ampere
W	-	Watt
Ω	-	Ohm
%	-	Percentage

LIST OF ABBREVIATIONS

Mpa	-	Megapascal
dB	-	Decibel
PWM	-	Pulse width modulation
RWHS	-	Rainwater Harvesting System
RWH	-	Rainwater Harvesting
RHS	-	Roof Harvesting System
PHS	-	Pond Harvesting System
Ah	-	Ampere hours
I2C	-	Inter-Integrated Circuit
PV	-	Photovoltaic
LCD	-	Liquid Crystal Display
MPMB	-	Majlis Bandaraya Melaka Bersejarah
MNKT	-	Majlis Negara bagi Kerajaan Tempatan
SPAH	-	Sistem Pengumpulan Air Hujan
SMKIS	-	Sekolah Menengah Kebangsaan Iskandar Syah
PSP	-	Pihak Juruperunding
LED	-	Light Emitting Diode
GSM	-	Global System for Mobile Communication
Wi-Fi	-	Wireless Fidelity
3D	-	Three dimensional
DC	-	Direct-Current
AC	-	Alternating-Current
IOT	-	Internet of Things
LDR	-	Light Dependent Resistor
CAD	-	Computer-Aided Design
RO	-	Reverse Osmosis
UV	-	Ultraviolet
USB	-	Universal Serial Bus

CHAPTER 1

INTRODUCTION

1.1 Background

Utilising a rainwater harvesting system has become an appealing possibility to minimise the amount of clean water consumed through the dry period and potentially mitigating the destructive effects of flooding during periods of high rainfall. Due to population growth, groundwater and pure water supplies are diminishing at an alarming rate. The lack of groundwater, potable water, and daily-useable clean water will have a significant impact on human society. The gathered water can be utilised immediately for irrigation or stored for future use in elevated ponds or subterranean reserves, such as aqueducts or shallow aquifers.

Next, water harvesting is a primordial practise one which has enabled certain cultures to thrive in mostly dry and arid terrain which other freshwater supplies, such as rivers and lakes, are rare or nonexistent. The ever-increasing population is creating an exponential increase in electricity demand, eventually leading to conventional energy sources running out of fuel in the not-too-distant future. The study has also been done to investigate the potential for deriving energy via sustainable sources in multiple forms. Furthermore, utilizing solar panels or rainwater harvesting on the rooftops and close-loop centralised control to ensure no pollutants out of buildings, are some of the methods that have been attempted to harvest energy from structures. The methods that have been tried to harvest energy from structures depend on the various building loads, such as lighting and heating. Rainwater harvesting is now one of the most valuable and practical strategies that can be employed. As such, it requires a great deal of focus and consideration in order to be used on a larger scale.

1.2 Rain exhibits flooding, necessitating the development of a Rainwater Harvesting System

A flood is a natural disaster when a significant watershed, such as a river or lake, overflows its customary boundaries and covers ordinarily dry ground. It can happen when the water level in the watershed rises above the average level. Several different occurrences, including intense rainfall, rapid snowmelt, coastal storms, and a dam or levee failure, may cause a flood. If we focus on rain, the water that falls as precipitation can have both positive and negative repercussions. It can replenish groundwater, relieve drought, and stimulate the growth of plants. On the other hand, excessive precipitation can lead to flooding, soil erosion, and water supply contamination. Installing adequate drainage systems, measures to lessen the number of impermeable surfaces, and increasing the use of green infrastructure in metropolitan areas are necessary to forestall the potentially disastrous effects of persistent rainwater flooding. There is a potential connection between a rainwater harvesting system and flooding, particularly in areas that experience an abundance of heavy rainfall. The purpose of a rainwater harvesting system is to collect and store rainwater for use later. It helps to reduce the amount of stormwater runoff and relieves pressure on the available water supply in the area.

1.3 Problem Statement

A rainwater harvesting system is an uncommon application of rainwater in modern times. This device gathers rainwater that falls on the house's roof and channels it through a conduit connected to a water storage tank. Rainwater is solely used for everyday consumption. Unfortunately, the collection of rainwater for producing renewable electricity is not yet fully established. There is a need for effective ways to analyse, manage, monitor, and control solar and hydroelectric energy production. The produced energy can be used as backup energy for various purposes, and it is a renewable energy source that does not harm neighbouring people or the environment. Nonetheless, maintenance work still necessitates money and skilled staff, which is a concern.

1.4 Project Objective

This project's primary objective is to develop a systematic and efficient approach for estimating the hybrid micro-hydro and solar PV generation in a rainwater harvesting system with a high degree of precision. The specific objectives are as follows:

a) To develop an integration of micro-hydro and solar PV electricity generation in small-scale rainwater harvesting systems.
b) To measure and design the rainwater volume monitoring system that can be displayed on LCD display.
c) To investigate the output performance of both renewable energy source for flushing toilet and irrigating plants.

1.5 Scope of Project

The scope of this project are as follows:

a) Circuit Design

- Design rainwater harvesting systems that are intended for collecting rainwater into a water storage container while displaying the level of water in and out, and also generate electricity for use in irrigation and flushing toilets via micro-hydro and solar PV generation.

b) Program Development

- To use Arduino IDE software to write a code or program for an Arduino Uno microcontroller to interact with the water flow sensor and perform measurements of water volume.

c) Software Development

- I use Proteus 8.1 software to create and connect circuits to display the micro-hydro and solar PV energy output of this rainwater harvesting system.

d) Hardware

- This rainwater harvesting required a connection from the tank to the irrigation and flush toilet applications. The energy produced required a micro-hydro generator, solar PV, battery, and charge controller to succeed in the hybrid for the small-scale system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review is a previous study drawn from a collection of academic references, such as journal articles and theses relevant to a specific research issue or difficulty, which circle the project's scope and setting parameters. The researcher will use the literature reviews to learn about other people's practices and then use those practices as recommendations for this study. The researcher will have a deeper comprehension of the subject matter, which will help them design or innovate new techniques. For this project's literature review, the primary areas of concentration were a rainwater harvesting system, a hybrid of two forms of renewable energy, and research on rainwater collection calculations.

2.2 Understanding Water Scarcity in the Literature

Freshwater scarcity has emerged as a critical concern in sustainable development, according to a review of the literature on previous studies. Population growth, a rise in quality of life, a shift in spending habits, and an increase in crop irrigation are the key factors causing the demand for freshwater to rise. The fundamental cause of worldwide water scarcity is the imbalance between freshwater demand and availability[1]. The biggest impact on human civilization from the expanding population will be the absence of groundwater, drinking water, and pure water that can be used on a regular basis. An alarming pace of underground or pure water resource depletion is occurring[2]. By capturing and using rainfall that would otherwise be wasted, rainwater harvesting can assist to solve this problem. The two categories of water use are consumerist and non-consumptive. When there is water loss during consumption, less water leaves the system than water is returned to it, this is known as consumption. Contrarily, a non-consumptive economy is one in which there are no minimum losses or losses that can be regarded as zero[3]. Yet, it can be challenging to put in place efficient rainwater harvesting systems in many areas due to a lack of infrastructure, money, knowledge, and education.

2.3 Rainwater Harvesting System

Traditional rain-water harvesting systems (RWHS) have evolved over millennia in response to the unpredictability of rainfall patterns. They have spiritual connotations and are incorporated with indigenous cultures. Even in the present day, traditional RWHS are still being discovered and could provide viable solutions to the current water shortage. They serve as a model for present-day sustainable water resource management. Traditional domestic RWHS have the potential to meet the demand for potable water in arid regions, particularly in underdeveloped rural areas.

However, in order to establish their potential function in sustainable water management, it is necessary to explore the ecological and human actions, social and economic systems, and sustainability issues affect one another. Rainwater harvesting systems have distributed control and provide a lot of room for adaptability to meet different needs[4].

Nowdays, rain harvesting systems collect a portion of the precipitation that falls and repurpose it for purposes such as irrigation, floor cleaning, and toilet flushing. They can also be used to produce electricity because of the possibility of energy emitted by the volume of water in the pipe used for the conduction system along with the kinetic energy released when the flow leaves the system. This allows them to be utilised in a number of different applications. The Pumps as Turbines (PaT) concept has been proposed to utilize the existing hydraulic systems in buildings and civil structures[5]. Figure 2.1 show a standard rainwater harvesting system normally used.

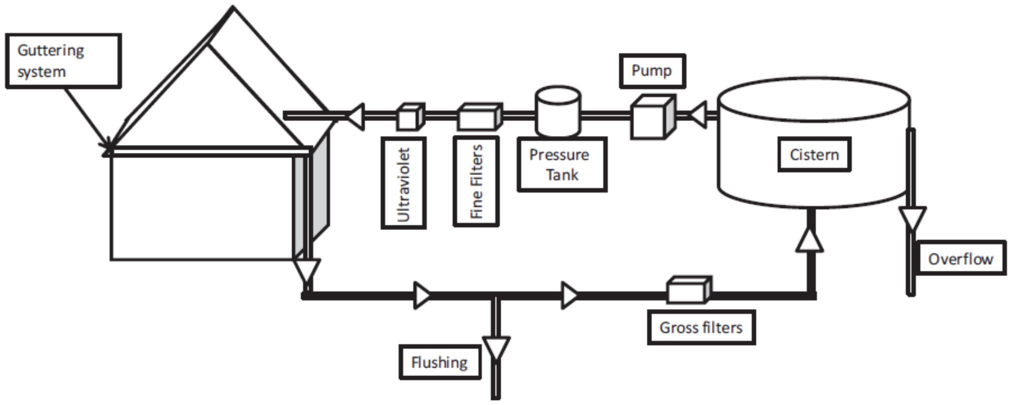


Figure 2.1 A Typical RWH system[6]

2.3.1 Rainwater Harvesting System in Malaysia

Malaysia has ample opportunity to gather rainwater for use in both agriculture and industry. However, due to its low level of community acceptance and protracted financial investment, the use of RWHS as a substitute water resource is restricted. Future obstacles include competitive pricing, widespread business building use, an affordable treatment system, successful policy execution, the use of environmentally conscious resources, a shift in public opinion, and reliable first discharge technology.

In [7] for example, in Melaka, the historic Melaka City Council (MPMB) has gazetted or mandated the use of a "rainwater collection and reuse system" as a result of the call of the National Council for Local Government (MNKT) in semi-detached houses, bungalows, separate buildings and even factories in Melaka collected rainwater can be reused for various purposes such as general cleaning, toilet flushing, and landscaping. Every consultant (PSP) who wants to apply for the approval of the building plan as stated must ensure that the installation (SPAH) follows the criteria that have been set, such as the position of the rainwater tank, the SPAH element, the appropriate roof design, and the optimal maintenance of the trough. MBMB stated that the benefits of using SPAH help in supplying water when a water crisis occurs, save water 25-30% of water and ultimately reducing the use of water bills. Figure 2.2 show the phamplet or poster for RWHS enforcement in Malaysia,Melaka.

Figure 2.2 RWHS Enforcement in Melaka[7]

Recommendations like offering incentives and restricting the usage of piped water are required for the adoption of RWHS on a broader scale. Malaysia seems to be a tropical nation with average annual precipitation of 2400 millimetres. The imbalance of precipitation has resulted in droughts and inundation, so it is essential to utilise rainwater for replacement water resources and swift flood mitigation[1].

2.4 Renewable Energy Generation from RWHS

One of the methods that can be utilized to collect rainwater from roof catchments and store it in reservoirs is referred to as rooftop rainwater harvesting (RWH). This water has the potential to be utilized in the production of power using turbines. It is also possible to store it in underground water reservoirs to provide for domestic requirements. The primary purpose behind collecting rainwater from rooftops is to store large quantities of it for later use[8]. Hydropower, piezoelectric panels, and vortex turbines are three examples of renewable energy sources that can be generated using rainwater gathering devices. The flow of water can be harnessed to produce hydropower, which is a form of renewable energy. The components that make up micro-hydropower systems include a turbine, a generator, and a control system[9]. In general, rainwater collecting systems have the potential to supply a source of renewable energy in the form of hydropower. However, the generations of hydropower and solar energy can be combined to produce renewable energy[10]. Renewable energy can also be produced through the combination of two separate sources that are merged.

2.4.1 Micro hydro generations

From previous studies, the process of producing electricity via the use of micro hydro generation is called harnessing the power of flowing water using a small-scale hydroelectric system[11]. In most cases, it is utilized to supply power to rural or otherwise inaccessible locations that are not connected to the national grid. There are two major categories that can be utilized to classify this micro hydro: internal turbines and external turbines. However, both types of hydro turbines have the same function, which is to produce electricity. Depending on the number of head and the flow rate of the water, the power output of a micro hydro system can be anything from a few kilowatts to several hundred kilowatts. It is essential to keep in mind that micro hydro systems operate at their optimal level of productivity when there is a constant flow of water throughout the year.

2.4.1.1 Internal Hydro turbine (in downpipes)

It is considered a waste of potential energy for rainfall to travel down gutters and into downspouts after it has already fallen as rain. Because the flowrate in a downpipe is often fairly low, it was presumed that an impulse turbine would be the kind of turbine that would be the most suitable. It is suggested that downspouts of homes and business structure be fitted with an efficient micro-hydro turbine system in order to harvest the unused energy potential of rainwater and utilize it to power devices[12]. It was discovered that the potential power that could be extracted has a direct relationship to the number of turbines that are contained within the pipe. As opposed to other methods of generating energy that utilize energy that is not renewable, the setting up and use of this technology are easier and cost-effective; however, in attempts to commercialize this, additional studies will be required in order to overcome its drawbacks[13]. Figure 2.3 shows the illustrates the components used on the interior and exterior of the microturbine's downpipe.

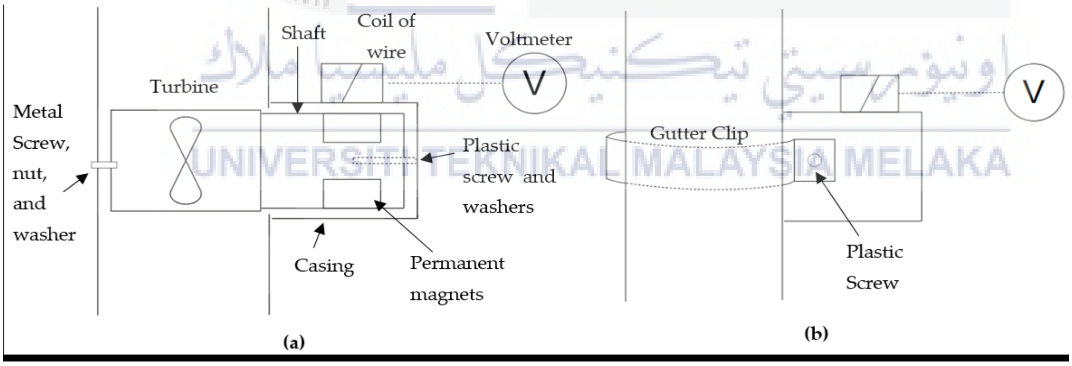


Figure 2.3Attachment shematics: (a) schematic of inside attachmentand support; (b) schematic of outside attachment and support[13]

2.4.1.2 External Hydro turbine (Pelton turbine)

Since its development in 1889 by Lester Pelton, there have been numerous attempts at analyzing the Pelton turbine over the course of the past century and a half. The researchers present a resource for the Bezier curve-based geometric construction of Pelton turbine containers. Nevertheless, because the pump does not have the parameters necessary for this operation, the amount of energy that can be harvested is notoriously low[5]. It includes a rotor with buckets throughout the entire turbine's perimeter. According to the figure, the buckets have an elliptical shape. As previously indicated, the complete available head is first turned into kinetic energy before a powerful water jet is directed into the buckets through one or two jets. As a result of the jet hitting the buckets, the rotor begins to turn. In order for the jet to deflect sideways after striking in the center and descend into the tail race at a velocity of 10% to 15% of initial velocity, the buckets are split into two halves with a split in the center. However, the water output velocity must be at a minimum in order to use the water's energy[14]. The figure 2.4 below show the pelton turbine construction that have been used bye the author.

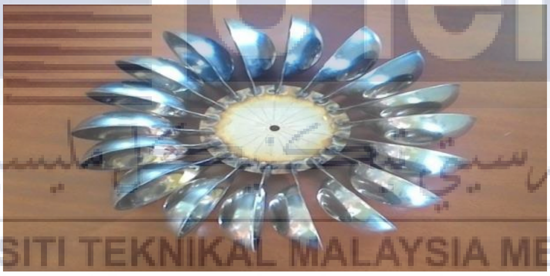


Figure 2.4 Pelton Turbine Design[14]

This study evaluated the mechanical and electrical efficiency of a proposed modification to a Pelton-type turbine so that it could be run on water collected from a rainwater harvesting system[15]. The system's overarching goal is to become a globally recognized sustainable electricity generation option that also increases the value of urban infrastructure and property[14].

2.4.2 Vortex Hydro Turbine

With a low hydraulic head, the gravitation water vortex power plant may transform the kinetic energy of a moving fluid into rotational energy. The method relies on a circular basin with a single drain in the middle. A water turbine is powered by the steady line vortex formed by the water above the drain. The water enters the chamber/basin perpendicularly and then tangentially. A large vortex emerges in the water over the basin's central drain. The vortex's rotational energy is extracted by a turbine and then transformed into electricity via a generator[16]. Figure 2.5 shows the drainpipe opening within chamber to generate a synthetic vortex.

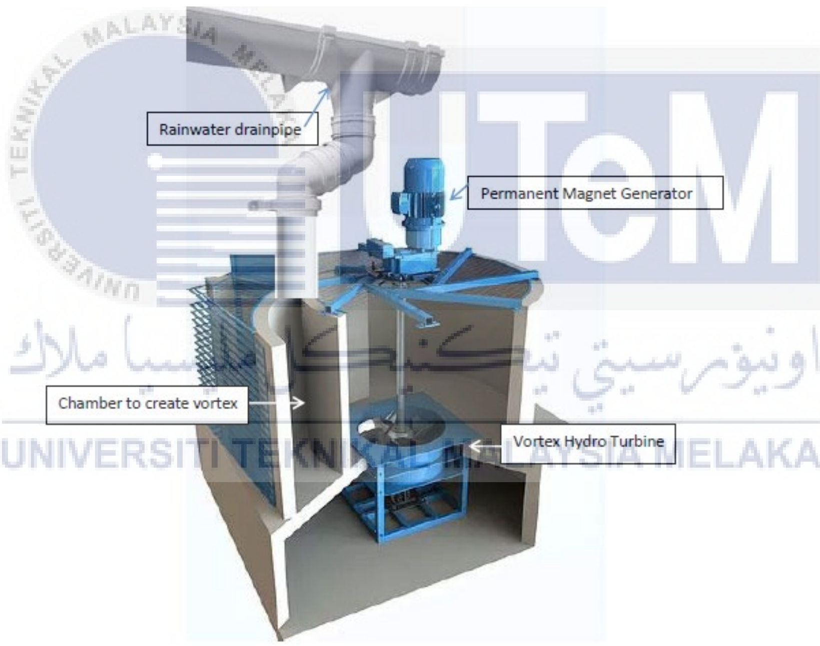


Figure 2.5 Drainpipe opening inside chamber to create artificial vortex[16]

The fluid pressure in a vortex is lowest near the center, where the speed is greatest, and gradually increases as one moves away from the center. Vortices in the fluid's circular motion contain a great deal of energy. A compact, low-cost, and easy-to-maintain hydroelectric energy production system is the key to independence via energy conglomerates and their harmful production of energy approaches[16].

2.4.3 Piezoelectric from rainwater

In contrast, a study on renewable energy harvesting can be conducted. It appears that piezoelectric components are the ideal choice for low power supply. Raindrops can be used as an energy harvester by converting mechanical energy into electrical energy when they hit a piezoelectric sensor. This energy can be used to power home devices such as LED lamps and fans. The reading of a piezoelectric sensor varies depending on the altitude of floors, even during intense rainfall[17]. Converting energy from mechanical sources, such as vibration or stress, into energy for electrical use is the fundamental concept. Piezoelectric plates turn raindrops' kinetic energy into electrical energy. A revolutionary comparison among piezoelectric materials to investigate water droplet source of energy for low-power electronic systems. The crystalline structure of piezoelectric materials is essential to their capacity to convert electrical energy to mechanical energy and vice versa[18]. Figure 2.6 show the cantilever diagram illustrating the piezoelectric effect.

Figure 2.6 Schematic of the cantilever under the piezoelectric effect[18]

When a drop of water descends on a structure, it produces a sudden force that causes the inside lattice fabric of the piezoelectric material to deform, resulting in an erosion of symmetry and, eventually, the generation of small dipoles. These dipoles have the cumulative effect of producing a sudden voltage across the electrodes[18].

2.5 Related Previous work of Rainwater Harvesting System

According to [19], the author state that rainwater harvesting (RWH) system at Sekolah Menengah Kebangsaan Iskandar Syah (SMKIS), Melaka, is to promote landscape sustainability is described in this research. An elevated tank, a sequential filter, and a storage tank were all part of the proposed RWH system. As part of the system, a fertigation pond and a turbine were erected to create an ecosystem for freshwater habitat and to generate energy. The RWH system was discovered to have lowered the rainwater flow rate in the previous drainage system by 50.9%, effectively lowering utility bills for landscape irrigation and the fertigation pond. The turbine produced 26.6 W of power, enough to power a scrolling message board in Taman Herba. The fertigation pond and turbine are excellent places for secondary pupils to gain hands-on experience.Figures 1.6 shows the conceptual design of rainwater harvesting system at SMKIS.

Figure 2.7 Conceptual design of rainwater harvesting system at SMKIS[19]

The construction of small dams has been proposed to reduce the speed of rainwater flowing which results in soil erosion and a dam was proposed to slow the stream. The captured rainwater was utilised to supply a fertigation pond and a turbine in Taman Herba, with the fertigation pond serving as a freshwater habitat and the turbine generating electricity[19]. Figure 2.8 show the schematic diagram that have been proposed at SMKIS.

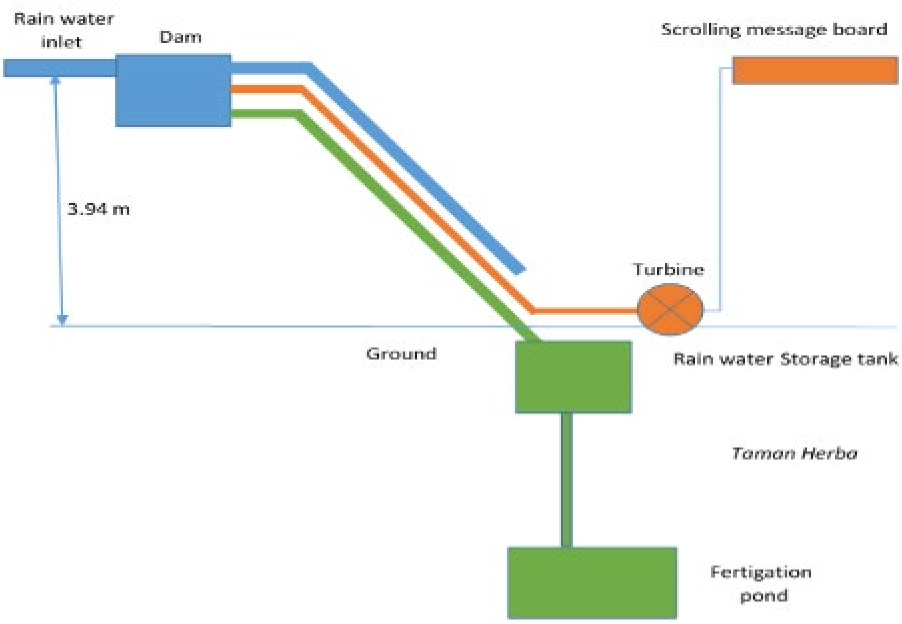


Figure 2.8 Schematic diagram of the RWH system at SMKIS[19]

The generated power may be predicted based on the vertical height of the hill, and other characteristics such as pipe diameter and type were calculated to achieve the set power generation. The RWH system's overall cost was reduced by using the marketed pipe size.

Due to emissions of harmful gases into the environment, which include sulphur dioxide, carbon monoxide, and nitrogen dioxide, that disintegrate in water and elevate its pH, [20] work focuses on rainwater harvesting quality control. The author use IOT application with ldr sensor and turbidity sensor to sense the water colour and level of turbidity. Next, the author of [21] study about smart water management using iot from rainwater harvesting system. The proposed water management model from this studied will assist individuals who face problems in the summer, such as a lack of water in cities and towns, as well as an excess of rain water during rainy seasons, by utilising the proposed gadget.

Lastly, review from this journal [22] studied about the structure and part of two varieties of RWHS, roof harvesting system (RHS) and pond harvesting system (PHS), were evaluated to determine their effectiveness in relation to the amount and purity of rainwater harvested as well as energy use. RHS is increasingly utilised, yet the effectiveness is restricted by its tiny scale. PHS has increased potential and could be implemented in newly developed, humid tropical urban areas. Typically, the greatest potential advantages of RWHS can be gained by contemplating rainfall amount, but for comparable roof area and water consumption rate, greater rainfall profundity is more dependable. Figure 2.9 and 2.10 shows the two varieties of RHS storage tanks: aboveground and underground . In the meantime, PHS storage is shows in Figure 2.11.

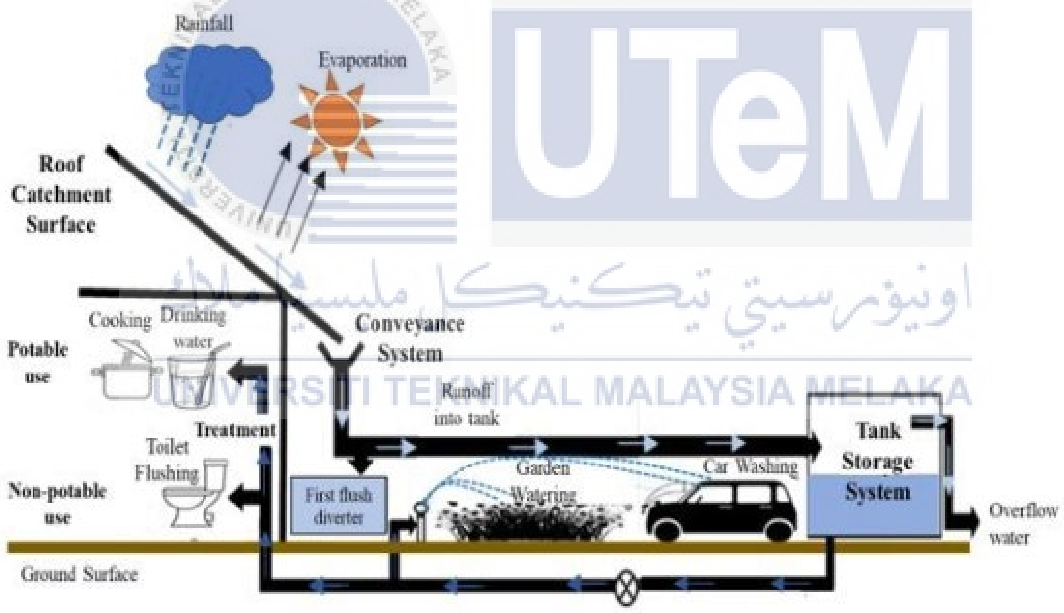


Figure 2.9 RHS aboveground storage tanks[22]

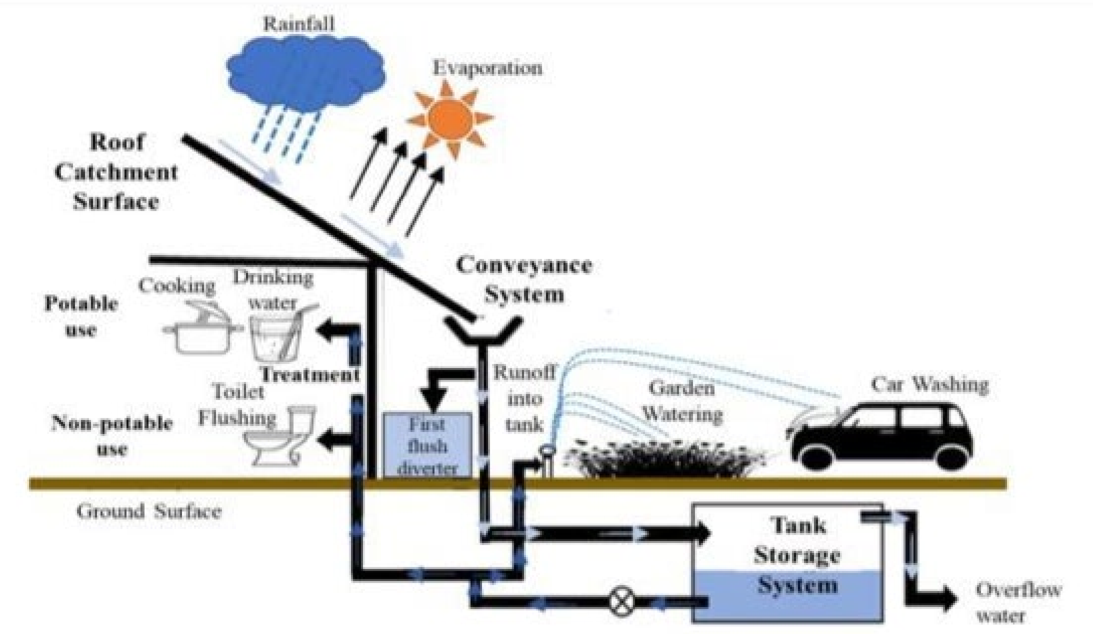


Figure 2.10 RHS underground storage tanks[22]

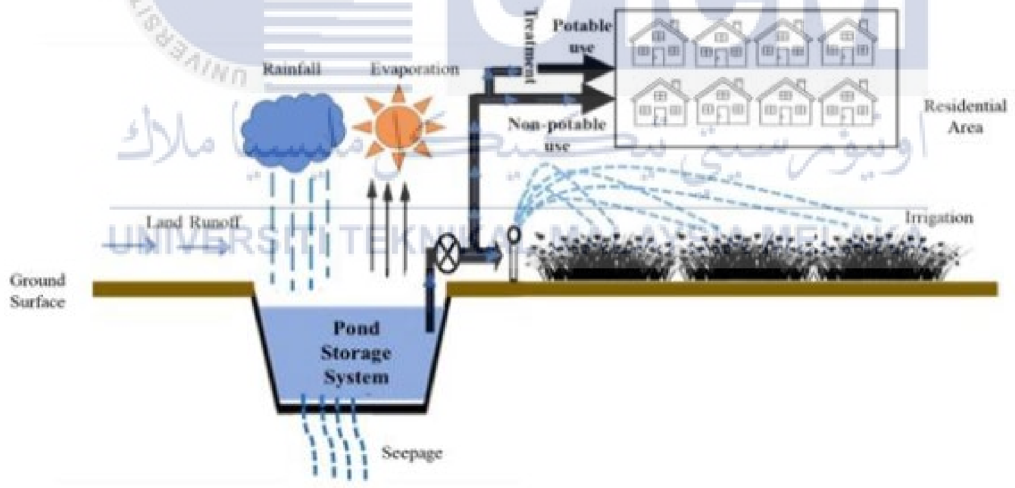


Figure 2.11 Pond Harvesting System[22]

2.6 Comparison of previous work

Everyone is aware that everything has both benefits and drawbacks. For comparing previous work, the entire article under consideration reveals a few shortcomings. For article [14] , one of the deficiencies that can be identified is the execution of projects that concentrate primarily on electricity generation and less on a more effective rainwater collection system. This is not consistent with the project under consideration, as the project must generate a rainwater harvesting system capable of producing the maximum amount of energy. In addition, the author of article [20] was only able to implement the use of iodine in the rainwater harvesting system and did not generate energy from it. The author was also unable to determine the purity of the water to be consumed and did not elucidate how to demonstrate that the tank contained rainwater.

Next, for article [21], the produced project cannot explain how much water has been collected and can only determine the water's quality if it is connected to a Wi-Fi and GSM-signal-free area. This will make it difficult for users to implement this rainwater catchment system in rural areas where there is no Wi-Fi connection, as the Arduino microcontroller is not powered by renewable energy, but rather by an undisclosed additional energy source.

Similarly, in article [19], the author employs mechanical calculations as opposed to electrical calculations and provides no energy or power output data. This endeavor also employs a microturbine that does not rely on batteries to store excess energy. In addition, article [13] concentrates solely on pipes below the vertical axis, where the shape of the earth fluctuates, and is therefore not applicable to houses or interior spaces. This undertaking is also due to the use of 3D printing in the construction of blades, the overall cost will increase, and the conduit must have a greater number of turbines proportional to the building's height to generate more energy. Aside from that, article [16] creates an undertaking. It requires a large space or water reservoir to generate a large and powerful vortex and does not provide a user/buyer reference for this project's energy production. The only deficiency in the project [23] is that energy production from hybrid solar and micro hydro is not described in detail. Nevertheless, each prior initiative still has its own benefits. Subsequent Table 2.1 shows the comparison and advantage of previous work from various methods.

Table 2.1 Comparison of previous work

No	Author(s)	Title	Functional	Remarks (Method and application)	Comment
1	Kumbhar, N J, Pravin, Patil, Aditya, Zunjar, Rohit, Salokhe, Sonam, Patil	Design and implementation of micro hydro turbine for power generation and its application	To generate DC power from low head water source	i. Tank,pipe outlet,pelton turbine,DC generator and inverter are among five component that need to be measured.	**<u>Advantage</u>** • Implementing use of a Pelton turbine, which is an external turbine that can produce additional electricity. • Using a DC generator is less expensive. • Utilization of an inverter to convert DC to AC for use with ac loads.
2	Rani, K. Pushpa, Srija, Krishna,	Rain water harvesting for smart water	Helps to manage the proper gathering of water	i. Designing of water level sensor.	**<u>Advantage</u>**

No	Author(s)	Title	Functional	Remarks (Method and application)	Comment
	Jyothianvitha, A., Ashasri, M., Mamatha, I., Rajesh, G.	management using IoT	during rainy season.	ii. Implementations of arduino,ultrasonic sensor and water level sensor for serve IOT requirement.	• Can determine the quantity of water that enters the water storage tank to prevent overflow.
3	Verma, Gaurav., Gupta, Shubhangi., Gupta, Rohan.	IoT Based Technique for Household Rainwater Harvesting	To solve the problem of quality of harvested water with the help of Internet of Things (IoT) which addresses the network	i. Applications of IOT board which is NodeMCU to compares the quality of water with predefined threshold value and further sends that data to the cloud for monitoring.	**Advantage** • LDR and turbidity sensors will allow you to determine the water's quality. • Due to the ease of locating and purchasing all the necessary components, the cost to produce this project is not too high.

No	Author(s)	Title	Functional	Remarks (Method and application)	Comment
			perspective of rain water harvesting		
4	Halim, Z. A., Din, A. T., Tokit, E. M., Rosli, M. A.M.	Development of Rainwater Harvesting System for Sekolah Menengah Kebangsaan Iskandar Syah Melaka	Reduced heavy rainwater flow rate at the existing drainage system, and at the same time beneficial as water saving, plant watering, energy generation and sustaining SMKIS	i. Design of rainwater harvesting system with dam and filtration to supplide the fertigation pond and turbine. ii. Consist of bernoulli equation in order to calculate the water velocity by assuming steady state flow.	**Advantage** • The utilized system is simple to comprehend and acquire for high school students as a reference tool. • Utilizing an external microturbine capable of generating more energy or power. • The introduced rainwater harvesting system can address the problem of soil erosion due to precipitation.

No	Author(s)	Title	Functional	Remarks (Method and application)	Comment
			landscape decoration		
5	Carter, Josie., Rahmani, Amin., Dibaj, Mahdieh., Akrami, Mohammad.	Rainwater Energy Harvesting Using Micro-Turbines in Downpipes	To capture thelatent energy potential of rainwater to power appliances	i. Designing in downpipes turbine using CAD software. ii. Use hydraulicbench to simulate 13 differents flow rates of water in to achieved optimum power generations from the turbine.	**Advantage** • can determine whether the number of blades affects the turbine's rotational speed. • CAD and 3D printing applications enable manipulation of the design blade so that every advantage of the designed blade can be evaluated.

No	Author(s)	Title	Functional	Remarks (Method and application)	Comment
6	Singh, Gurmit	Gravitation water vortex power generator in domestic plastic water tank integrated with RO + UV Water purifier (Drinking Grade)	To provide electricity that was sufficient for powering lights and charging batteriesin rainy locations with limited electricity access	i. Uses of vortex phenomenon to generate electricity. ii. The vortex, which powers the turbine, occurs above the central drain of the water vortex power plant. iii. The vortex that drives the turbine is located above the water vortex	**<u>Advantage</u>** • This endeavor does not require complicated wiring and components. • A water purifier is used to clean captured rainwater and after use. • This undertaking can also be implemented by utilizing chiller and cooling tower overflow water.

No	Author(s)	Title	Functional	Remarks (Method and application)	Comment
				power plant's central outflow.	
7	Sie Woo, Wong., Ong Ling, Sylvia AI., Che Chien, Lim., Julini Goel, Petrus	Development of Micro Solar-Hydro Power Generation System for Rural Area Under Tropical Climate	To create a standalone hybrid micro solar-hydro power generation system specifically designed for small communities in rural areas	i. Integration of an 18V/100W solar panel, a 12V microhydro generator, a DC-AC inverter, and a 12V 20Ah deep cycle cell for sustained energy production. ii. The system incorporates an auto photo switch	**Advantage** • This endeavor employs a micro hydro turbine that is readily available on the market for purchase by the public. • Hybrid 2 renewable energy, such as solar and micro hydro turbine, plus the use of an automatic switch controller able to generate optimal power.

No	Author(s)	Title	Functional	Remarks (Method and application)	Comment
				on/off photocell for shifting purposes.	• The use of batteries permits the storage and use of energy as required.

2.7 Summary

According to the findings of several studies, the implementation of an efficient rainwater harvesting system may have a beneficial impact on the end users of the product. Access to other energy sources that can be combined with this system can help ensure its continued operation. It is vital to have an accurate assessment of the amount of rainwater collected to make the most efficient use of the water that falls from the sky, which can be accomplished with the right kind of gear. Finally, installing this rainwater harvesting system can help alleviate water-related issues and save money on costs associated with its use.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will discuss the methods and techniques used in this project, as well as the hardware and software required to finish it. The primary focus of this discussion will be on the efficiency of using hybrid micro-hydro and solar PV generation in a rainwater harvesting system. To ensure that our venture is fruitful, we will be utilizing a microcontroller based on Arduino Uno in addition to the required software.

3.2 Selecting and Evaluating Tools for a Sustainable Development

It is crucial to carefully pick and evaluate the tools and technologies that will be used to gather and analyze data to develop and operate a rainwater harvesting system. There are many methodological factors to consider, including how well sensors work, how well various tools and software play together, and how the project will affect the environment. Cost-benefit analyses and data accessibility for multiple stakeholder groups are only two examples of social and economic factors to consider when deciding which tools to use. Numerous methods exist to back up these theoretical considerations, including life cycle assessments for gauging the project's ecological footprint, open-source software for fostering transparency and accessibility, and field tests for gauging sensors' precision. Researchers and practitioners can increase their rainwater collecting-sensing initiatives' efficiency, longevity, and significance by selecting and evaluating appropriate technologies.

3.3 Methodology

This research will present several challenges, including the need for specialized techniques or methods and analysis of information. The term "methodology" can be understood as a unit of logic used to explore deductive reasoning or as a method for completing a task. By measuring the volume of collected rainwater and the amount of water that flows in and out of the system, this small-scale prototype will assess the efficiency of a hybrid micro-hydro and solar PV production system in a rainwater harvesting system.

3.3.1 Project architecture

A basic graphical depiction of the complete project or of programming is a flow chart. It displays the processes in a sensible order. The project's development from start to finish is shown in the flow chart. The flowchart shows how a project develops from beginning to end. Research and data gathering phases, as well as understanding of every language used for programming and functional design, are all included in pre-development. After the pre-development stage, the first stage of development is to incorporate the data collection procedure into the Arduino coding. In the post-development phase, the simulation results are products into hardware and apps for the final time. Figure 3.1 shows how the project's operational framework functions so that the system flow can be understood.

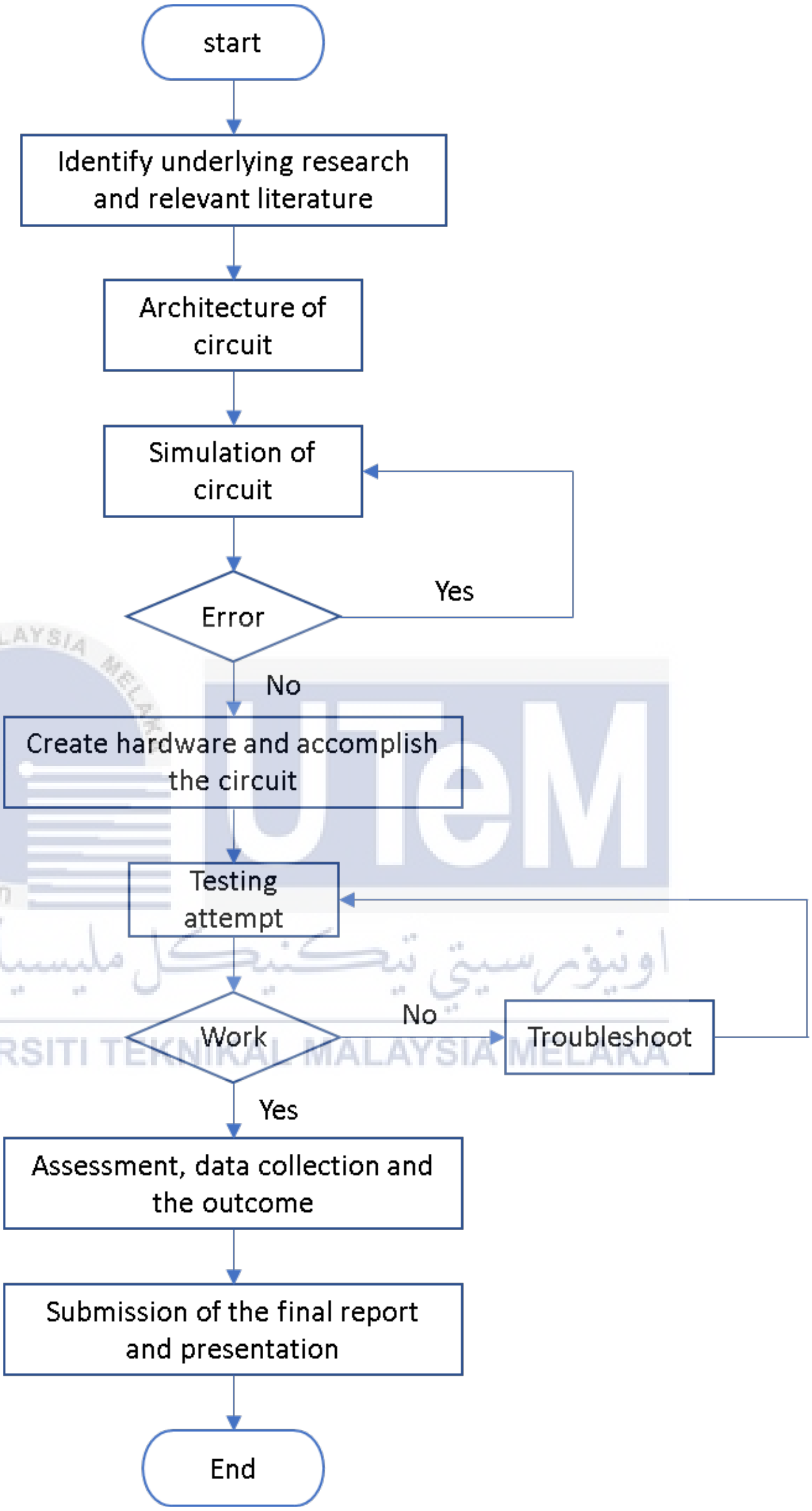


Figure 3.1 Flowchart of system

3.3.1.1 Project system flowchart

The system flowchart for this project demonstrates a pattern that is more concentrated on how this project is investigated using hardware development, an experimental approach, and also software combination. Figure 3.2 displays the project's functioning system so that the system flow can be clarified.

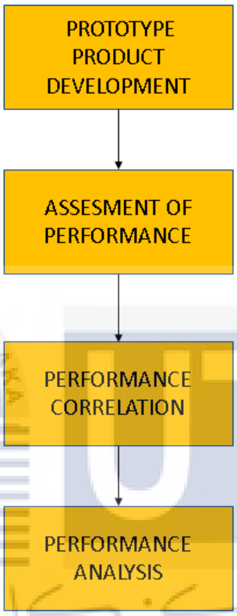


Figure 3.2 Functioning System Diagram

a) **Prototype product development**

Water tanks (for collecting rainwater), a micro hydro turbine generator, a DC motor pump, a solar panel, a charge controller, a battery, an LCD display, a water flow sensor, a pvc pipe, a buck converter, and an Arduino microcontroller will be used to build the project.

b) **Assesment of performance**

This project will be exposed under rain condition to determine the durability of each individual component. In addition to this, the output of the water turbine will be measured against the disparity in water speed, and a multimeter and a sensor that measures water flow will be attached to the system.

c) **Performance correlation**

The performance of this project will be evaluated based on its capacity to generate hybrid power from two sources, namely solar and microhydro, and on the amount of rainfall that can be collected and used to flush containers and irrigate crops. Both of these metrics will be monitored at the end of the project.

d) **Performance analysis**

The effectiveness of the newly developed project will be evaluated with regard to its output capacity and its consistency.

3.4 System architecture

The primary consideration for conducting this operation is the amount of water that enters the rainwater storage tank as measured from the rain gutter, amount of rainwater can be used for irrigation and flushing tanks, alongside how much power is successfully generated by the solar and micro hydro turbine because of the hybridization of the two sources for the charge controller. In addition, solar energy is used as another source of energy for this system if there is no rainfall. The stored voltage will then be divided between the battery and the Arduino UNO. Figure 3.3 depicts this project's block diagram.

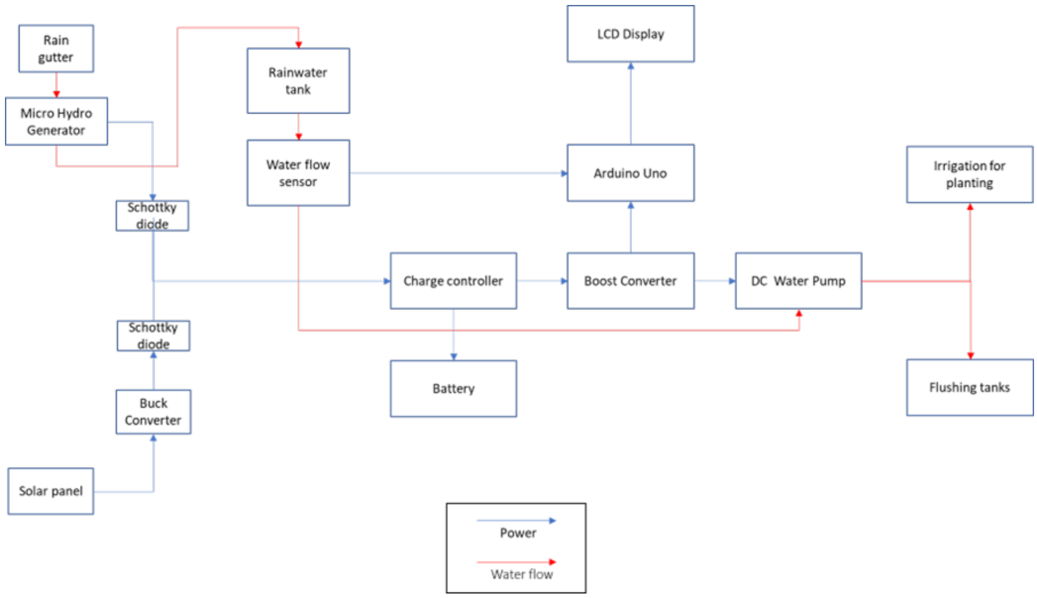


Figure 3.3 Project Block Diagram

a) The hybridization of solar energy with a micro-hydro turbine, which operates on direct current (DC), is achieved by connecting the two sources in series via a Schottky diode that prevents current from re-entering between them.

b) When the voltage and current are produced by the two sources, they are delivered to the charge controller, which controls the amount of current and voltage that goes into the battery, which serves as a storage device for extra energy.

c) At the same time, the water flowing into the micro hydro turbine will also flow into the water flow sensor and directly into the tank to collect metrics of the water flowing into the rainwater storage tank.

d) The boost converter can regulate the voltage from the battery and utilize it to power the Arduino uno.

e) The reading from the water flow sensor will be read to the Arduino microcontroller and will be displayed on the LCD display.

f) DC water pump will work to move water to irrigation for planting purpose and into flush tank toilet.

3.5 Software Flowchart

This segment of the course centres on the progression of the experiment conducted for this project, which employs an Arduino Uno microcontroller to regulate the relay responsible for activating or deactivating the DC water pump and presenting the volume and flowrate of water accumulated in the water tank for irrigation and toilet flushing. This flowchart simplifies and clarifies the tasks that must be completed prior to the implementation of the project by illustrating and condensing the steps required to conduct an experiment. The experimental procedure is illustrated in the flowchart presented in Figure 3.4.

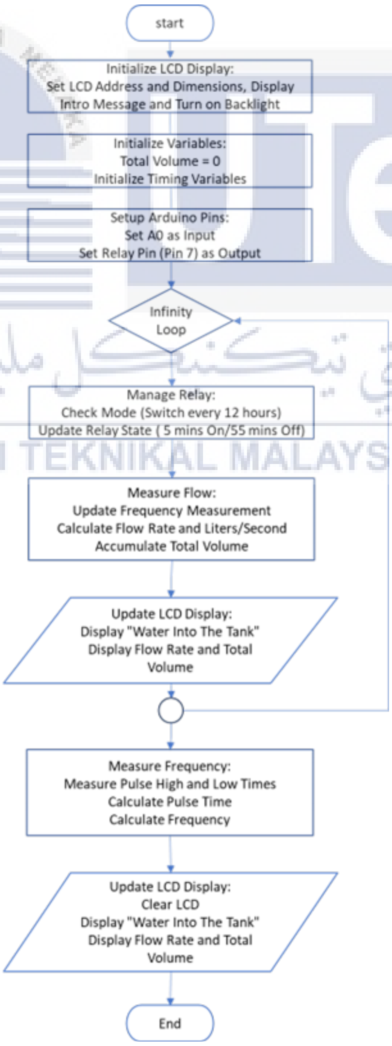
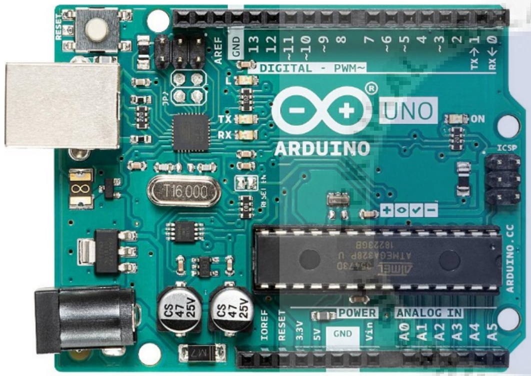


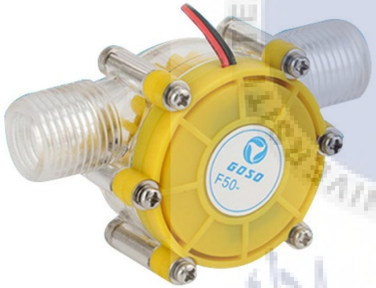
Figure 3.4 Flowchart of simulation for solar panel

3.6 Hardware components

Hardware can assist us in accurately representing all our actual data and labor, making it an essential component of any project, specifically an initial model. Simulator output is reliant on computer/software computations which ignores other aspects like environmental factors, so projects that solely rely on simulation software will not be able to collect actual data or work. The greatest gear enables us to learn about the software and hardware components while also enhancing our design and modelling abilities. Table 3.1 shows the applications and descriptions that component including for this project.

Table 3.1 Description of each component used

Component	Application	Description
1. Arduino Uno Microcontroller 	Home automation, robotics, Internet of Things (IoT) projects, data logging and monitoring, wearable electronics, education, prototyping and do-it-yourself projects, automation and control systems, art and interactive installations, and scientific research are uses for Arduino microcontrollers.	• Arduino Uno is a widely used microcontroller board acknowledged for its straightforward nature, versatility, and user-friendliness. It is fueled by an ATmega328P microcontroller and has 1KB of EEPROM, 2KB of SRAM, and 32KB of flash memory for storing data. • 14 digital input/output pins, 6 analogue input pins, USB interface, power selections, Integrated Development Environment (IDE), and expansion shields are included. The Uno is compatible with a variety of expansion

Component	Application	Description
		shields, including Ethernet, Wi-Fi, motor control, and LCD displays, among others.
2.Micro Hydro Turbine (F50-12V)  	Micro hydro turbines are tiny turbines that use moving water to produce electricity. They can be used for many different things, such as microgrids, environmental monitoring, water pumping, off-grid power systems, rural electrification, and educational initiatives.	• The Micro Hydro Turbine F50-12V is a small-scale hydroelectric power generation system developed to convert the kinetic energy of moving water into electrical energy. The turbine is designed for low-head water sources, such as streams, rivers, and irrigation channels. • The permanent magnet generator (PMG) system converts the turbine's mechanical energy into electrical energy and includes regulation of voltage and protection

Component	Application	Description
		mechanisms to ensure stable and secure operation.
3.Solar Panel (18V 30W Polycrystalline) 	A 30W solar panel can be used for various applications, including off-grid lighting, portable charging for devices, small electronics and gadgets, RV or boat charging, remote monitoring systems, solar education and demonstration, small water pumping, and emergency power. It provides a moderate amount of power from solar energy and is suitable for powering small-scale electrical devices and systems.	• The 18V 30W Polycrystalline Solar Panel is a widely available, compact, and efficient solar power generation system. This device has a power rating of 30 Watts and produces 18 Volts of direct current (DC). • Solar cell components are formed from polycrystalline silicon, allowing for reduced production costs than monocrystalline panels, making them a cost-effective choice for solar power generation. The solar panel is designed to

Component	Application	Description
		transform sunlight into electricity with an average efficiency of 15 to 17 percent.
4. Water Flow Sensor(YF-S201) 	Water flow sensors, usually referred to as flow metres, have a variety of uses in many processes and industries. They are essential for water supply and distribution, HVAC systems, industrial operations, irrigation systems, water treatment and filtration, aquaculture, water conservation, research, and development since they are used to quantify the rate of water flow in systems.	• This is a black YF-S201 Water Flow Measurement Sensor with a 1 to 30 liter per minute flow rate. • It will start operating with water Pressure < 1.75MPa, Voltage (V) 5 ~ 18 and maximum current draw15mA at 5V. • Integrated magnetic hall effect sensor emits an electrical discharge with each revolution. • The hall effect sensor is isolated from the water pipe, allowing it to remain dry and secure.

Component	Application	Description
5. Rechargeable LI-ION Battery 18650 	Rechargeable lithium-ion batteries, more precisely the 18650 variant, find extensive application in a variety of sectors and contexts on account of their dependable nature and economical pricing. These devices function as multifunctional power solutions, offering reliable energy storage, portable power, and reserve power for a wide range of applications.	• The 18650 Rechargeable Li-Ion Battery is an adaptable power source that is compatible with a wide range of electronic devices due to its nominal voltage of 3.7V and high capacity of 4200mAh. It ensures safe and efficient operation with its 4.2V 450mA output and protection against overcharging and draining at 2.75V and 4.2V, respectively. The low discharge rate, absence of memory effect, and environmental benevolence of this battery are well-known characteristics.

Component	Application	Description
6. CN3791 MPPT Solar Panel Lithium Ion Battery Charger Charging Controller Module 	The versatile applications of the CN3791 MPPT Solar Panel Lithium Ion Battery Charger Charging Controller Module water pumping systems powered by solar energy, portable solar energy solutions, and educational initiatives that centre around solar technology. The functionality of this module enables the recharge of LiPo batteries and the efficient utilisation of solar energy, making it applicable to a vast array of green electricity applications.	• The CN3791 MPPT Solar Panel Lithium-Ion Battery Charger is engineered to charge single-cell LiPo batteries while efficiently harnessing solar energy via maximum power point tracking (MPPT). This small module features 2-pin JST connectors that facilitate straightforward connection between the solar panel and battery. • It functions at a PWM toggling frequency of 300KHz, which permits a maximum charging current of 2A. Designed to operate with DC 12V power sources, its input voltage renders it a highly suitable

Component	Application	Description
		option for optimizing the solar charging process for lithium batteries.
7. Buck Converter (LM2596 2596 DC-DC) 	There are several uses for buck converters, often known as step-down converters. They are utilised in power supplies, battery-powered devices, solar-powered devices, telecom and datacom equipment, LED lighting systems, portable electronics, automotive electronics, industrial control systems, and renewable energy systems.	• The input of this buck converter is between DC 3 - 40V and output DC 1.5 - 35V which is continuously adjustable. The current is 3A (Max.), 2A(rated) and use a heatsink if output current is >1A. • The thickness of circuit boards is 36um with built in SANYO fixed Aluminum capacitor without isolation buck and non-synchronous rectification. • Conversion efficiency is up to 92% when input voltage is 12V and switching frequency is 150kHz.

Component	Application	Description
8. LCD Display (20x4 Character IIC I2C) 	It is utilised in industrial control systems, data logging and monitoring, automation systems, advanced DIY electronics and robotics and , information display systems, educational tools, Internet of Things (IoT) applications, prototyping and development, and industrial control systems.	• The LCD display has a size of 20 characters per line and 4 lines, providing a total of 80 characters. It is composed of a 5x8 dot matrix, allowing the display to show alphanumeric characters, symbols, and custom-defined characters. • The IIC/I2C interface simplifies the wiring and control of the display, requiring fewer pins from the microcontroller. • The display is typically equipped with a built-in blue backlight, which illuminates the characters for improved visibility in different lighting conditions.

Component	Application	Description
8. LM2596 DC-DC Adjustable Step-Down Voltage Converter Module 	The LM2596 DC-DC Adjustable Step Down Voltage Converter Module is a versatile tool used to regulate or reduce voltage from a higher source to a specified lower level, ensuring precise and consistent power supply to electronic circuits or devices. Its primary application is converting car battery voltage to a suitable voltage for mobile devices or vehicle electronic components.	• The LM2596 DC-DC Adjustable Step-Down Voltage Converter Module is an energy-saving power supply with a 92% conversion efficiency. • It offers consistent power output with a 150KHz toggling frequency and accurate voltage regulation with a tolerance of ±0.5%. • It can handle input voltages between 4.75V and 35V, making it suitable for various electronic applications requiring voltage conversion and regulation.

Component	Application	Description
9.Dc Water Pump (Mini USB DC5V 2.3W Micro Brushless) 	The mini USB DC5V 2.3W micro brushless DC water pump is a versatile device with various applications. It is commonly used in water cooling systems, aquariums, hydroponics, fountains, portable water transfer, DIY projects, educational demonstrations, and arts and crafts.	• This DC water pump is brushless, permanent magnetic rotor, maintenance-free. The stator and circuit board were sealed by epoxy resin. Enclosed with static sealing, not dynamic, which can avoid leaking problems. • It uses a USB interface with DC 5V input. These water pumps are small, high efficiency, low consumption and low noise (less than 35db). It can operate in Wide temperature resistance ranges from 0°C to 100°C.

3.7 Software development

This software is crucial to the operation of the whole project system. Without this application, it is impossible to build a connecting circuit for the system and verify the circuit's operation on a working system. Table 3.2 presents the function of software used for this project.

Table 3.2 Description of each software used

Software	Application	Description
1. Proteus 8.1  	The versatile software programme Proteus is frequently employed in electrical and electronic engineering. Circuit design and simulation, the creation of microcontrollers and embedded systems, PCB layout design, virtual prototyping, Internet of Things development, fault finding, industrial automation, computation of signals, and automobile electronics are some of the main applications. Proteus assists in building, simulating, and	• Handy and powerful application developed for letting the designers build and verify the circuit boards easily. • Has a very well-organized interface which has got all the necessary tools and commands for creating circuit boards.

Software	Application	Description
	testing electronic systems for a variety of applications because to its vast features and capabilities.	• Schematic capture mode which will display all the devices as well as their connections. • Source Code tab where you can make modifications at the basic level for every element which is the part of loaded project.
2. Arduino IDE	The software tool known as the Arduino IDE is used to programme Arduino microcontrollers. It is used in robotics, wearable electronics, sensor interface development, interactive art, IoT development, automation and control systems, tracking data, and home management. The Arduino IDE is extensively used for a variety of electronic projects, from simple	• It offers an intuitive user interface and several features that make it easier to write, compile, and upload code to Arduino boards. • The Arduino programming language, which is based on a condensed version of C++, is

Software	Application	Description
	prototypes to complicated applications in numerous sectors and educational institutions, thanks to its intuitive user interface and comprehensive library support.	supported by the IDE. It has a compiler, a debugger, a code editor with syntax highlighting, and a serial monitor for interacting with Arduino boards. • Additionally, a variety of libraries and examples are available in the Arduino IDE to aid users in getting their projects off the ground quickly.

3.8 Solar and Battery Configuration

In order to guarantee the attainment of project objectives, it is imperative to configure the solar and battery systems such that the battery can serve as a reserve power source in the event of nocturnal solar inactivity. This configuration of solar panels and batteries is crucial for the correct operation and working of the load. As a result, a sequence of computations has been executed in order to improve the precision of the battery and photovoltaic configuration.

Calculation: The total load used for the system is 1.1 watt

• Step 1 (Solar panel size)

- ❖ Energy = 1.1 × 24hours = 26.4 Wh
- ❖ Battery voltage = 3.7V
- ❖ Days of autonomy (DoA) = 1 days
- ❖ BBTM = 1.05
- ❖ PSH (Peak Sun Hour) = 4
- ❖ DoD (Depth of discharge) = 50%

Solar panel size = Energy / PSH / System efficiency

= 26.4 / 4 / 0.85 = W

= 7.76W / (30W)

= 0.26 ≈ 1 panel

• Step 2 (Daily Average)

= (Ac average / inverter efficiency) + Dc average

= 26.4Wh

• Step 3 (Battery bank capacity)

= (Daily average × DoA × BBTM) / DoD

= (26.4 × 1 × 1.05) / 0.5 = 55.44Wh

• Step 4 (Battery bank)

= (Batery bank capacity) / (Battery voltage)

= 55.44 / 3.7 = 14.98Ah

= 14.98Ah / Battery Ah = 14.98 / 4.2 Ah

= 3.56 ≈ 4 battery

Two interpretations can be drawn from the calculation performed in the preceding section: the quantity of solar panels and batteries that will be utilised for this undertaking. It is evident that the maximum number of solar panels to be utilised is one, whereas the maximum number of batteries utilised is four. In pursuit of achieving the goals of the project, the four batteries will be configured in parallel to enhance their operational current and prolong their useful life (in Ah).

3.9 Project design and installation

Initial consideration was given to the type of material that would be utilised as well as the dimensions of the project form in a simple design. For a robust and stable structure, the approximate measurement is determined by considering the height and dimensions of the rainwater storage reservoir. Durability, resistance to heat and corrosion, and a selection of iron slotted angle bar have been emphasised. The slotted angle bar cutting procedure utilised for this undertaking is illustrated in Figure 3.5.

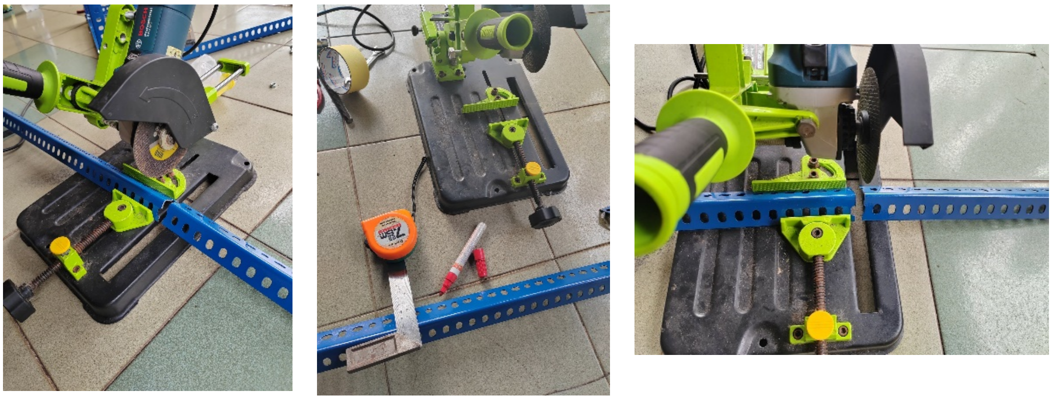


Figure 3.5 Cutting process of the slotted angle bar metal

Following the cutting phase, the assembly process is executed with precision and diligence, resulting in a project that appears streamlined and sturdy, as illustrated in figure 3.6. Figure 3.7 illustrates the ultimate configuration of the project, which comprises four sections: one designated for the installation of the solar panels, another for the storage of the electronic components, and a location to accommodate the rainwater reservoir, piping, and water turbine and pump.

Figure 3.6 Assembly process

Figure 3.7 Final shape of the project

3.10 Experiment setup for Case A, Case B and Case C

The initial sequence of experiments, designated case A, aims to investigate the capacity of solar energy to generate power. This power is supplemented by a solar charge controller, which charges the battery and controls the load on the project system, which consists of a relay-controlled motor (DC water pump) and the liquid crystal display (LCD) that indicates the water volume in the tank. case B, the second series of experiments, is nearly identical to case A with the exception that the micro-hydro turbine is substituted with a solar function as the energy source. Case C, the third and final series of experiments, aims to evaluate the performance of hybrids comprised of diodes connected in series at positive wired between two energy sources, namely micro hydro turbines and solar panels. Table 3.3 shows the source type and mode of each case related.

Table 3.3 Description of each experiment conduct

Cases	Source Type	Mode
Case A	Use only solar	12 hours - 55 minutes waterpump off and 5 minutes waterpump on
Case B	Use only micro-hydro turbine	12 hours - waterpump off
Case C	Use hybrid of solar and micro-hydro turbine	12 hours - 55 minutes waterpump off and 5 minutes waterpump on

3.10.1 Experiment setup for Case A

The experiment configuration for Case A is illustrated in Figure 3.8. In this configuration, a parallel-connected 18V 30W solar panel was utilised to charge the battery. In order to facilitate charging and safeguard against overcharging, a solar charge controller is integrated with the solar system.

Figure 3.8 Case A experiment setup

3.10.2 Experiment setup for Case B

The experimental configuration for case B is illustrated in Figure 3.9. In this configuration, a micro hydro turbine with a capacity of 12V 2.5W is connected to a battery arranged in parallel. To facilitate data collection, the water supplied to the turbine is water from a pipe with a half opening.

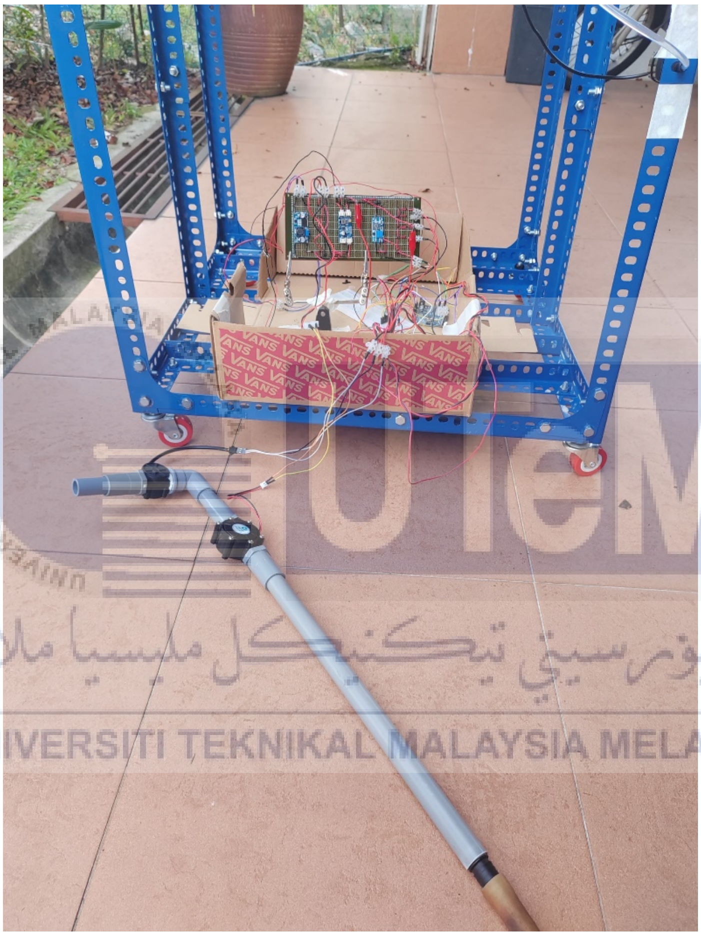


Figure 3.9 Case B experiment setup

3.10.3 Experiment setup for Case C

Figure 3.10 depicts the experimental configuration pertaining to case C. Parallel connections are established between a micro hydro turbine with a capacity of 12V 2.5W and a solar panel with an output of 30W operating at 18V. For the purpose of establishing a hybrid connection between the two energy sources, a diode is positioned on each positive wire. This configuration prevents the re-entry of current or voltage from the source. Consequently, all utilised resources can be safeguarded against harm. Information regarding the current generated by the hybrid reaction is extracted from the positive wire that is connected in parallel.

Figure 3.10 Case C experiment setup

3.11 Circuit design for data collection

This section describes the experimental circuit utilised for the three predetermined case breakdowns, denoted as case A in Figure 3.11, case B in Figure 3.12, and case C in Figure 3.13. **Case A** is an experiment in which data is collected regarding the generation of voltage and current for solar power, the process of charging and discharging batteries, and ultimately, the energy consumption of the boost converter load. In contrast, **case B** pertains to an experimental investigation wherein data was gathered regarding the voltage and current generated by the turbine, the battery's charging and discharging cycles, and the energy consumption of the load at the boost converter. In the final, **case C**, the experiment is conducted by collecting data on the load at the boost converter, the energy consumption of the battery, and the voltage and current produced by the hybrid solar and turbine.

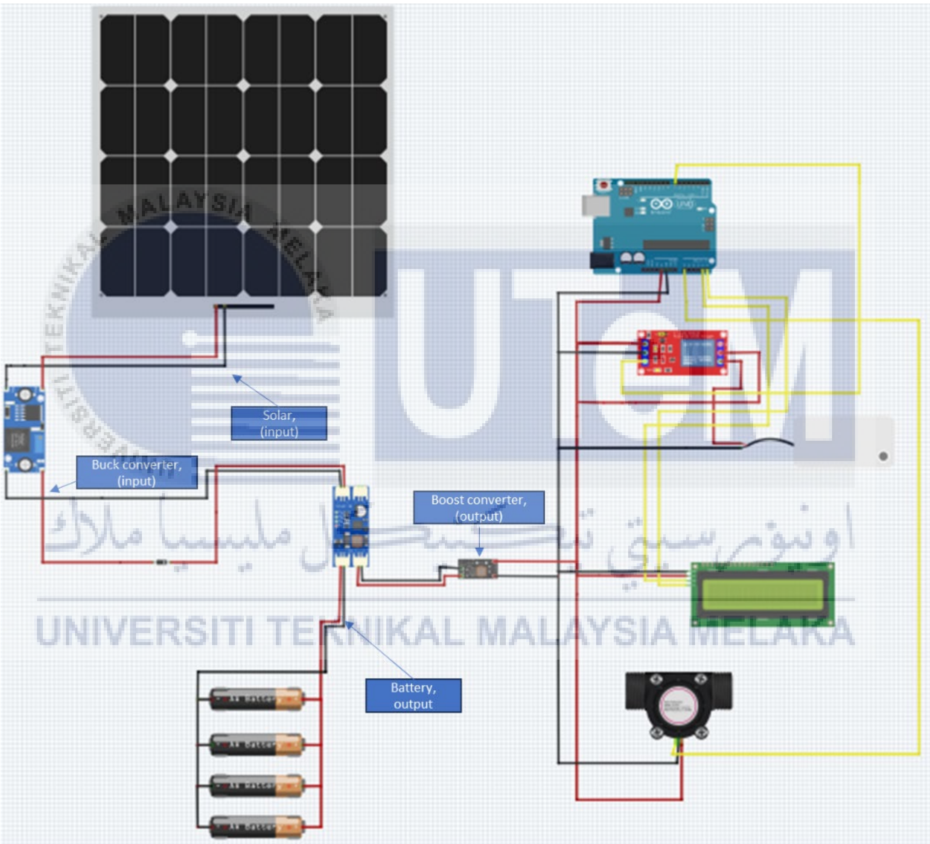


Figure 3.11 Case A experiment circuit

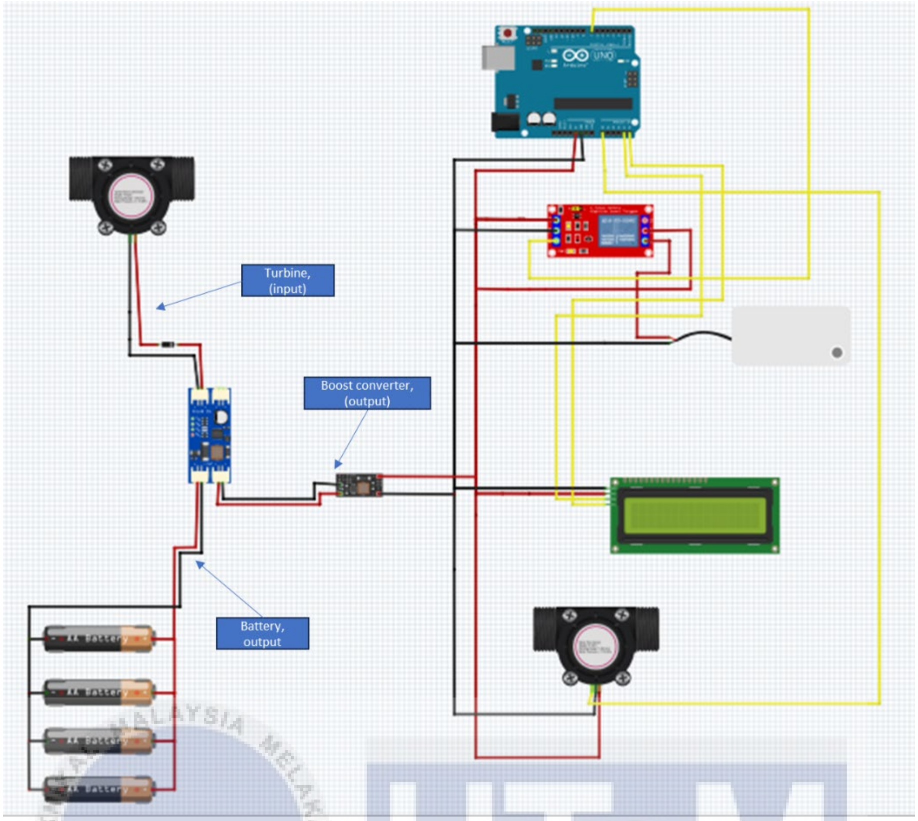


Figure 3.12   Case B experiment circuit

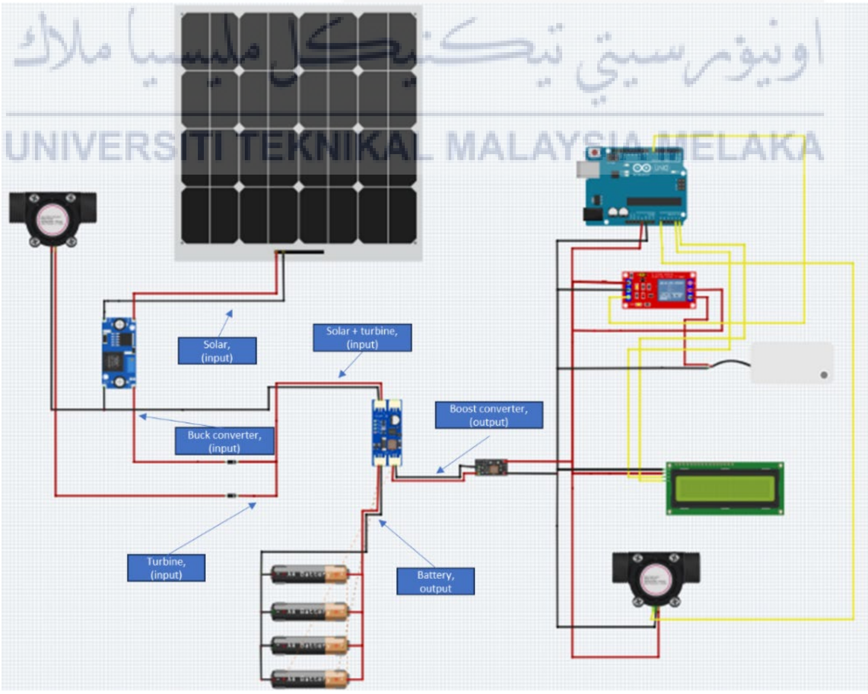


Figure 3.13   Case C experiment circuit

3.12 Gantt Chart

Project handlers utilize Gantt charts to schedule tasks logically and sequentially, understand task dependencies, monitor progress, effectively allocate resources, and communicate with readers. It visually represent the project's progress and timeline, making it easier to communicate updates, discuss priorities, and ensure everyone is on the same page. Gantt charts are a useful communication tool for project handlers, making it easier to communicate updates, discuss priorities, and ensure everyone is on the same page. Furthermore, Gantt charts contribute to effective project planning, monitoring, and communication, allowing us to manage complex projects more efficiently. Overall, a Gantt chart is used for presenting the project's schedule and timeline to ensure that the consistency and organization of the project's development will improve as the project develops. Table 3.3 demonstrates the Gantt chart throughout the entire PSM1 and PSM2 progress.

Table 3.4 Presents the Gantt chart for the entire progression of PSM1 AND PSM2

No.	Task	PSM1														PSM2													
	Weeks	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	Briefing for PSM 1 by JK PSM, FTKEE																												
2	Project Title Conformation and Registration																												
3	Briefing with Supervisor																												
4	Study the Project Background																												
5	Drafting Chapter 1: Introduction																												
6	Task progress evaluation 1																												
7	Drafting Chapter 2: Literature Review																												
8	Table of Summary Literature Review																												
9	Drafting Chapter 3: Methodology																												
10	Work on the Software/Hardware																												
11	First Draft submission to Supervisor																												
12	Task progress evaluation 2																												
13	Submission Report to the Panel																												
14	Presentation of BDP1																												
15	Drafting Chapter 4: Analyze Data and Result																												
16	Data Analyze and Result																												
17	Record the Result																												
18	Drafting Chapter 5: Conclusion and Recommendation																												
19	Compiling Chapter 4 and Chapter 5																												
20	Submit Latest Report to Supervisor																												
21	Finalize the Report																												
22	Presentation of BDP2																												

3.13 Summary

This chapter discusses a proposed technique to establish a new, effective, and integrated strategy for estimating projects based on a rainwater harvesting system with hybrid micro-hydro and solar power. This methodology aims to develop a more accurate and comprehensive method. The primary objective of the approach that has been suggested for usage is to arrive at an estimate that is straightforward, less exacting, and useful in a manner that will not result in a material reduction in the accuracy of the outcomes of the project. In addition, the purpose of this strategy is to make the most of this project's production and development by using all the components that are now on the market. This method's primary goal is not to achieve the highest possible degree of accuracy but to maximize productivity, ease of use and manipulation, and the viability of use on networks primarily focused on residential and rural areas.

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Introduction

This chapter presents the results and analysis utilised in the development of three series of experiments aimed at creating a sustainable and efficient project system. For greater data precision, the experimental setup incorporates the exact solar panel and micro hydro turbine utilised in the real undertaking. Nevertheless, environmental factors such as shading effect, which can impede the functionality of solar panels, and varying water pressure factors, which cause inconsistent water flow, may introduce inconsistencies into the collected data. It is essential to note that the purpose of this study is to demonstrate the proposed methodology for accomplishing the project's objectives irrespective of the precise location of the project area.

4.2 Data collection

Data has been successfully acquired and analysed as a result of the experiments that were actually carried out. For the purpose of obtaining voltage and current readings generated by solar panels and micro hydro turbines as ashown in Figure 4.1 for case A, Figure 4.2 for case B and Figure 4.3 for case C, the data collected is based on real-time measurements and is obtained through the utilisation of electrical measurement tools such as clamp metres and multimeters. In order to determine the rate at which water is flowing through a system, a water flow sensor has been built by utilising a microcontroller (an Arduino Uno) in conjunction with the appropriate programming.

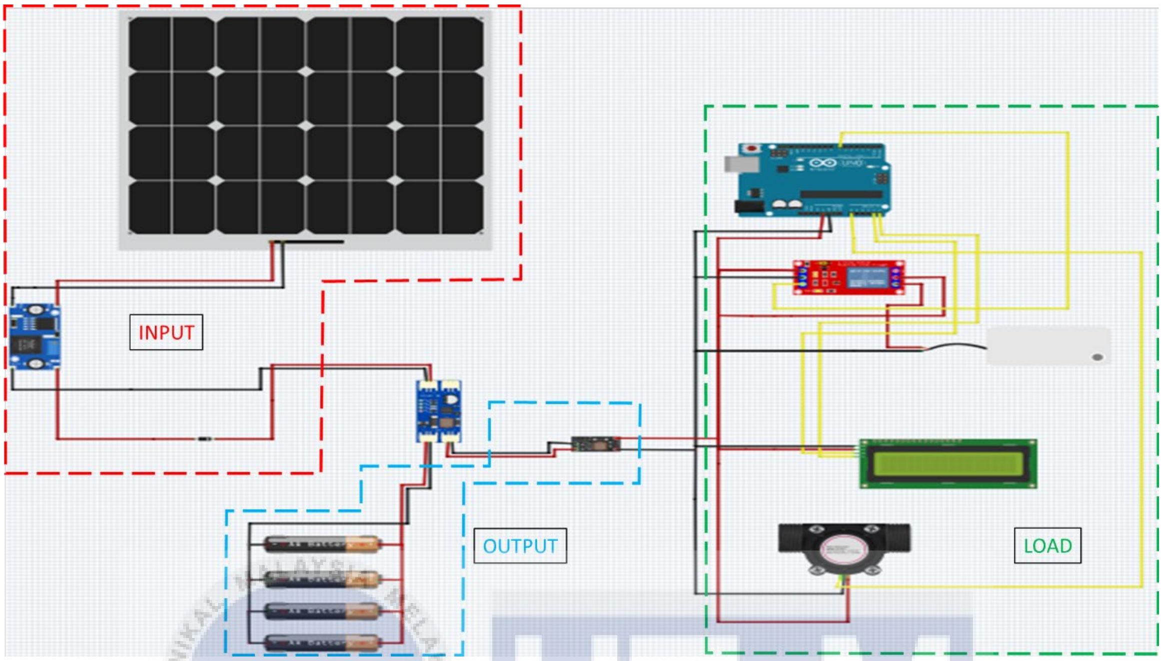


Figure 4.1 Point of data measured in Case A

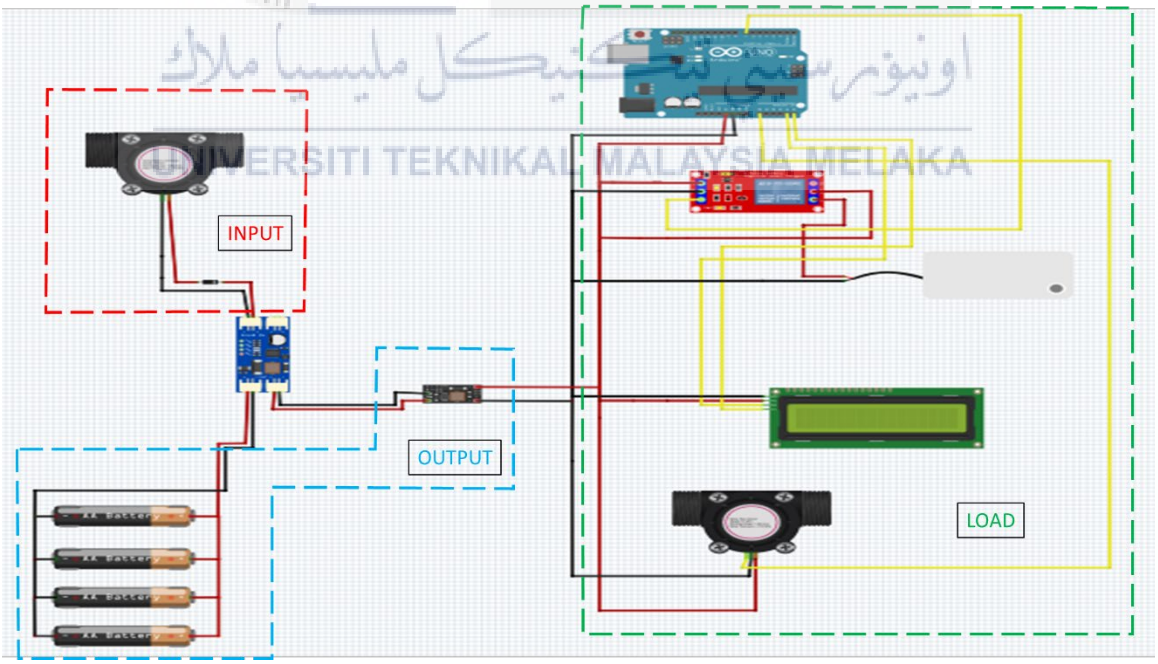


Figure 4.2 Point of data measured in Case B

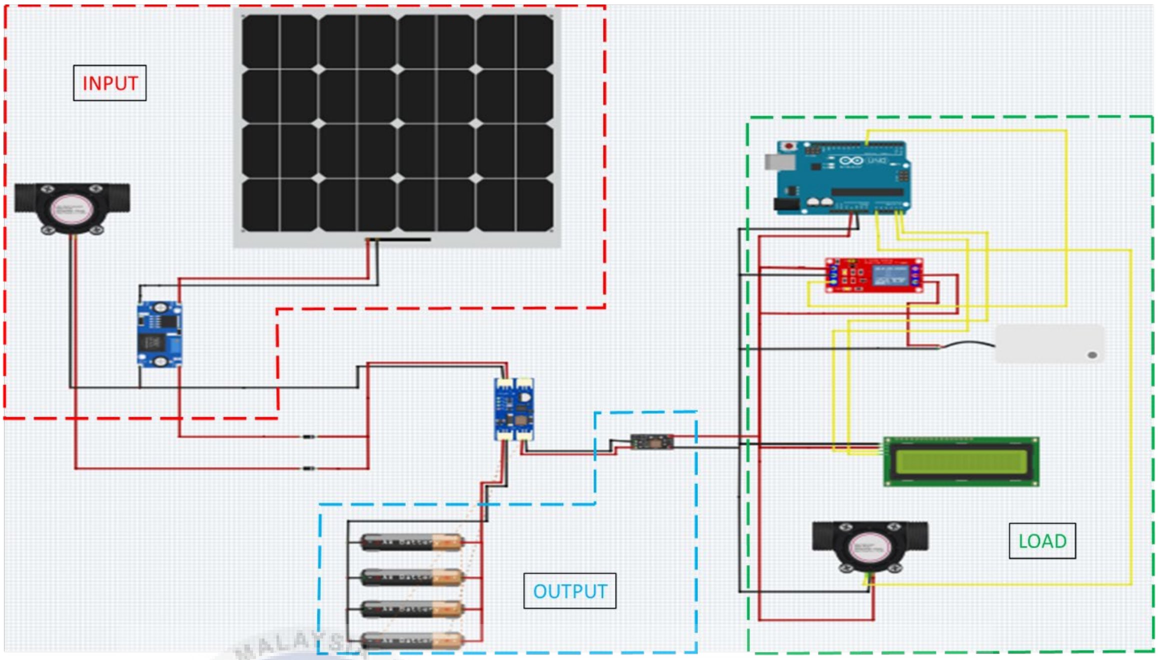


Figure 4.3 Point of data measured for Case C

4.2.1 Case A

The data has been divided into two distinct components: the input and the output. This is to optimise the organisation and comprehensibility of the analysis. Information is gathered at intervals of 55 minutes when the water pump is turned off and at intervals of 5 minutes when it is actually functioning. The time that is stated in the Arduino Uno code that is utilised to govern the relay is what determines anything that has been mentioned above

4.2.1.1 Input data for Case A

The data that was successfully gathered for the Case A experiment for input analysis, which was carried out at 25/11/2023 from 9.20 in the morning to 725 in the evening, is represented in Table 4.1.

Table 4.1 Input data for Case A experiment

Input for case A			
Time	Solar voltage,V	Solar current,A	Power,W
9.20am	19.2	0.13	2.50
9.25am	19.6	0.07	1.37
10.20am	20.6	0.13	2.68
10.25am	20.8	0.08	1.66
11.20am	21.7	0.13	2.82
11.25am	21.2	0.1	2.12
12.20pm	21.5	0.15	3.23
12.25pm	21.4	0.1	2.14
1.20pm	20.3	0.14	2.84
1.25pm	20.8	0.08	1.66
2.20pm	21.3	0.22	4.69
2.25pm	20.7	0.11	2.28
3.20pm	20.1	0.13	2.61
3.25pm	20.6	0.01	0.21
4.20pm	19.5	0.16	3.12
4.25pm	21.7	0.03	0.65
5.20pm	19.5	0.14	2.73
5.25pm	20.2	0.05	1.01
6.20pm	8.9	0.04	0.36
6.25pm	9.15	0.06	0.55
7.20pm	3.76	0.03	0.11
7.25pm	3.26	0.02	0.07

Figure 4.4 and Figure 4.5 presents an illustration of the periodic progression of voltage and current, and power trends for a system powered by solar energy. The first graph depicts the voltage and current of the sun as time passes. With minimal fluctuations, the voltage appears to be relatively stable, remaining around 20 volts for the majority of the day before, as anticipated, a sharp drop-off in the evening to 3.26 volts. In contrast, the current exhibits considerably greater variability, characterised by notable peaks and troughs. This may suggest that the solar panel output is influenced by fluctuating sunlight intensity or cloud cover. The second graph shows the solar power in watts, calculated as the product of voltage and current. This graph also shows variability corresponding to the current's fluctuations, with power levels peaking at around 4.5 watts at 2.20pm.

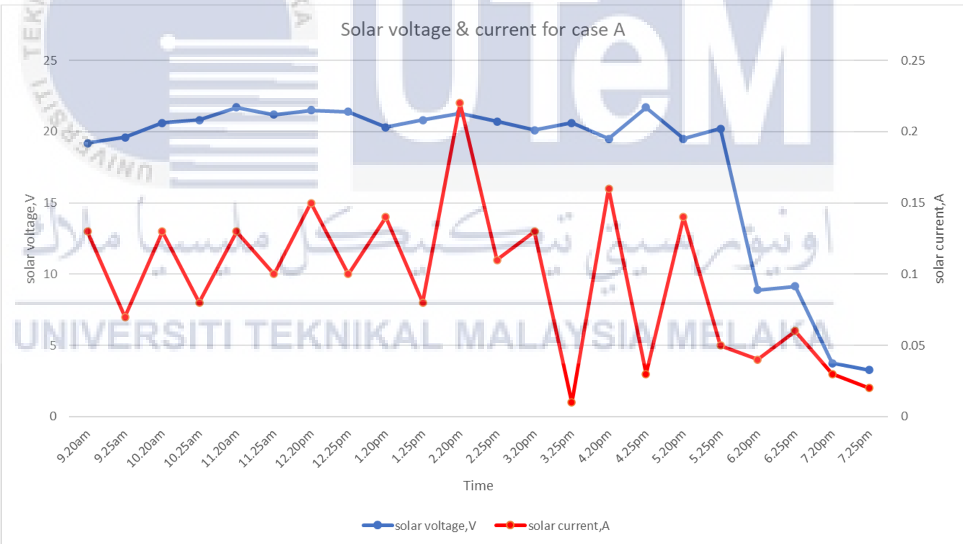


Figure 4.4 Input voltage and current graph for Case A

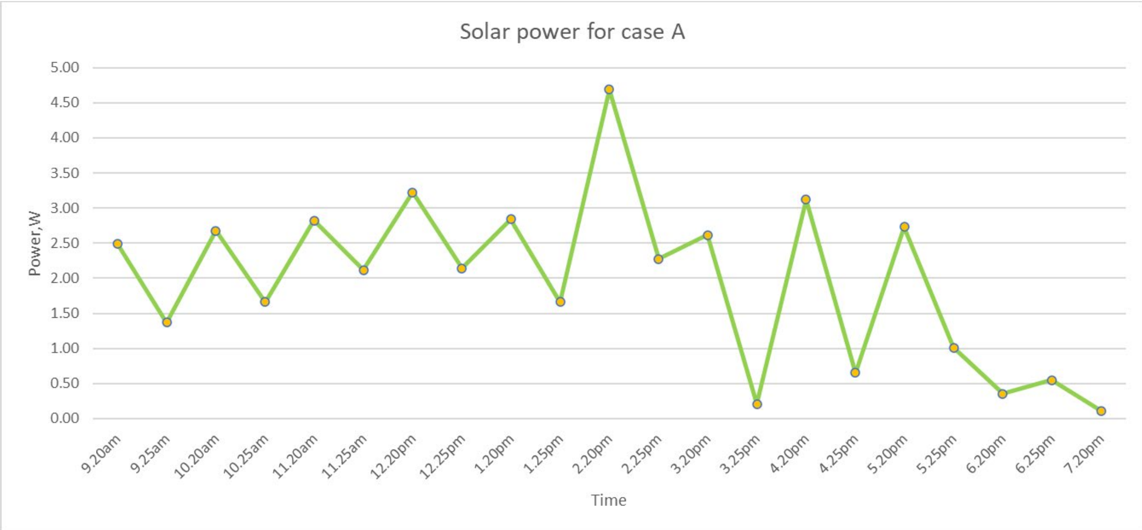


Figure 4.5 Input power graph for Case A

4.2.1.2 Output data for Case A

The data has been gathered satisfactorily for the Case A. The data depicted in Table 4.2 and table 4.3 illustrates an output analysis experiment that spanned the time period from 9:20 in morning time to 7:25 in the evening.

Table 4.2 Output data (battery) for Case A experiment

Time	Battery voltage,V	Battery current,A	Power,W	Mode Charge,C or Discharge,D
9.20am	4.1	-0.32	-1.31	Discharge
9.25am	4.1	0.09	0.37	Charge
10.20am	4.1	0.12	0.49	Charge
10.25am	4.1	0.08	0.33	Charge
11.20am	4.2	0.12	0.50	Charge
11.25am	4.1	0.06	0.25	Charge
12.20pm	4.2	0.11	0.46	Charge
12.25pm	4.2	0.04	0.17	Charge
1.20pm	4.1	0.12	0.49	Charge
1.25pm	4	-0.06	-0.24	Discharge
2.20pm	4.1	0.22	0.90	Charge
2.25pm	4	-0.03	-0.12	Discharge

Time	Battery voltage,V	Battery current,A	Power,W	Mode Charge,C or Discharge,D
3.20pm	4.1	0.1	0.41	Charge
3.25pm	4	-0.13	-0.52	Discharge
4.20pm	4.2	0.11	0.46	Charge
4.25pm	4.1	-0.09	-0.37	Discharge
5.20pm	4.1	0.14	0.57	Charge
5.25pm	4	-0.08	-0.32	Discharge
6.20pm	3.8	-0.26	-0.99	Discharge
6.25pm	3.95	-0.08	-0.32	Discharge
7.20pm	3.76	-0.34	-1.28	Discharge
7.25pm	3.85	-0.16	-0.62	Discharge

Table 4.3 Output data (overall load) for Case A experiment

Time	Load ON voltage,V	Load ON current,A	Power in,W	Load 0FF voltage,V	Load OFF current,A	Power out,W
9.20am	4.1	0.27	1.11	5	0.12	0.60
9.25am	4.1	0.11	0.45	5	0.08	0.40
10.20am	4	0.28	1.12	5	0.08	0.40
10.25am	4	0.14	0.56	5	0.11	0.55
11.20am	4.1	0.28	1.15	5	0.22	1.10
11.25am	4	0.14	0.56	5	0.1	0.50
12.20pm	4.1	0.28	1.15	5	0.21	1.05
12.25pm	4.1	0.13	0.53	5	0.1	0.50
1.20pm	4	0.28	1.12	5	0.21	1.05
1.25pm	3.9	0.14	0.55	5	0.11	0.55
2.20pm	4	0.34	1.36	5	0.25	1.25
2.25pm	3.9	0.17	0.66	5	0.13	0.65
3.20pm	3.9	0.23	0.90	5	0.15	0.75
3.25pm	3.9	0.09	0.35	5	0.02	0.10
4.20pm	4.1	0.25	1.03	5	0.15	0.75
4.25pm	4	0.08	0.32	5	0.05	0.25
5.20pm	4	0.25	1.00	5	0.17	0.85
5.25pm	4	0.11	0.44	5	0.06	0.30
6.20pm	3.5	0.29	1.02	5	0.17	0.85
6.25pm	3.86	0.11	0.42	5	0.06	0.30
7.20pm	3.55	0.22	0.78	5	0.1	0.50
7.25pm	3.78	0.04	0.15	5	0.02	0.10

The Figures 4.6, 4.7, 4.8, and 4.9 depict the power trends and periodic progression of voltage and current for a system that is propelled by a overall load and battery. In light of discharge and charge cycles, it is customary for a lithium-ion battery to maintain a voltage greater than 4.0 V for the majority of the day. When the voltage level consistently exceeds the nominal value of 3.7 V, it generally signifies that the battery is in good health and has a positive charge. Negative current signifies discharge, whereas positive current signifies charging. Denoting power consumption from the battery are current values that are negative. Potential causes include load consumption or inefficiencies within the system. Variable loads or intermittent charging, which may be induced by passing clouds, have the potential to result in current fluctuations. Throughout the charging process, the power output rarely exceeds 0.5 W. Given that the battery has a capacity of 62.16 Wh, the charging rate is comparatively sluggish; therefore, solar energy alone would likely not be adequate to fully charge the battery within a considerable time period. The overall load ensures a relatively stable voltage, with only slight fluctuations of around 5.0 volts. Stability is a critical factor in applications that require a consistent level of voltage. Sharp current surges may indicate that the load is fluctuating in power consumption or exhibiting intermittent power on/off cycles. The frequency of these spikes indicates the presence of a control mechanism that cycles the burden or a periodic load. As the voltage readings indicate, the fact that my system maintains stable voltages for operation is encouraging overall. Given that the system is engineered to operate the water pump autonomously and that the current is sufficient to supply it, the battery's evident adequate recharging facilitates the system's proper operation.

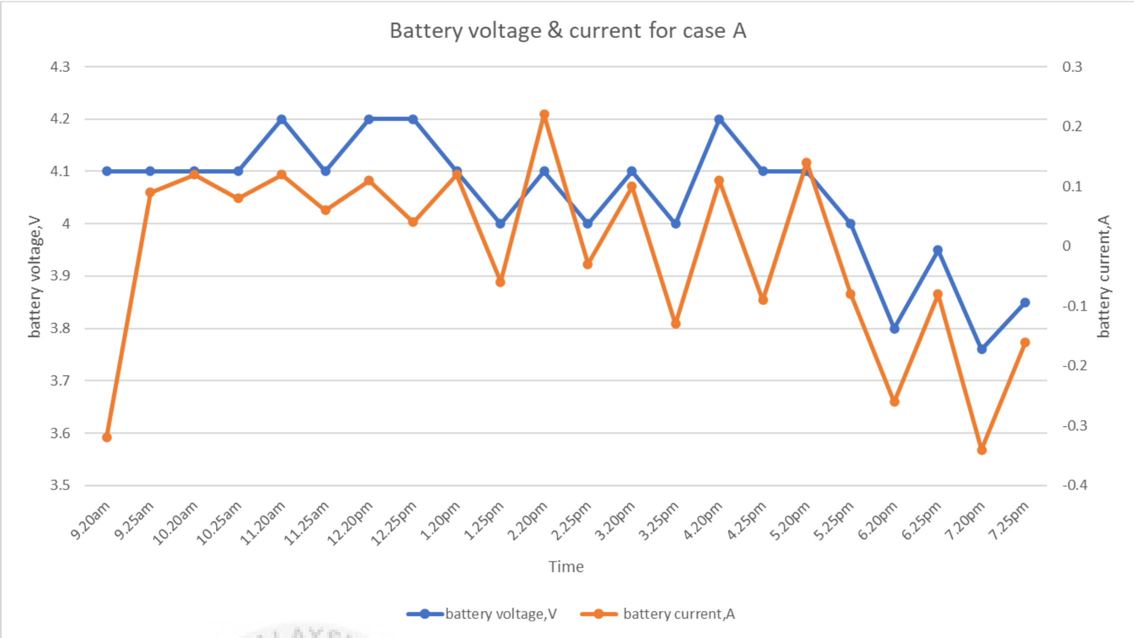


Figure 4.6 Output (battery) voltage and current graph for Case A

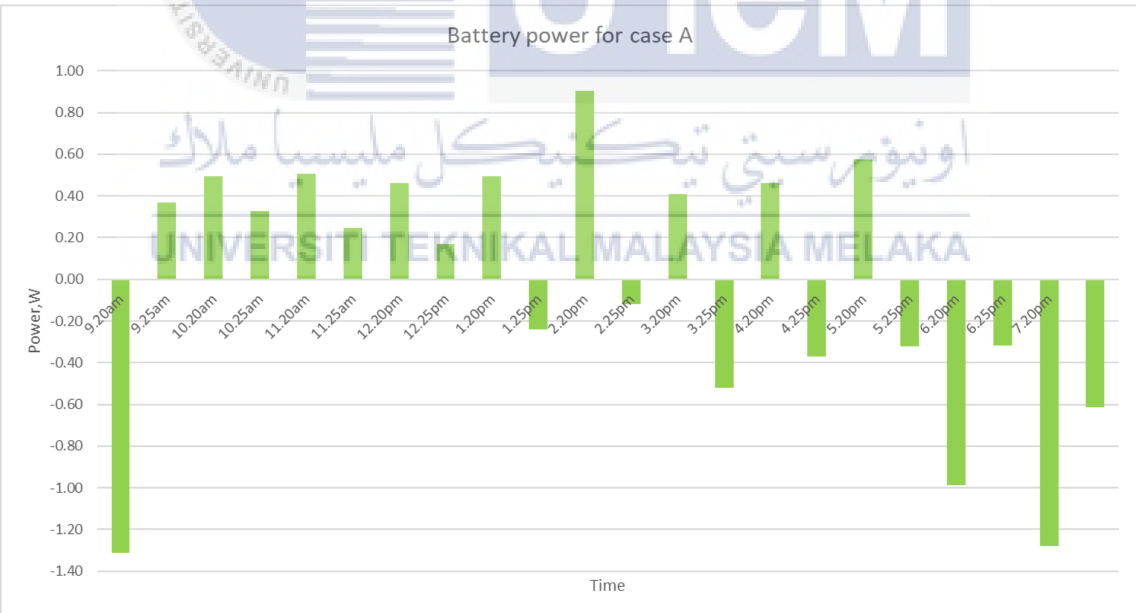


Figure 4.7 Output (battery) power graph for Case A

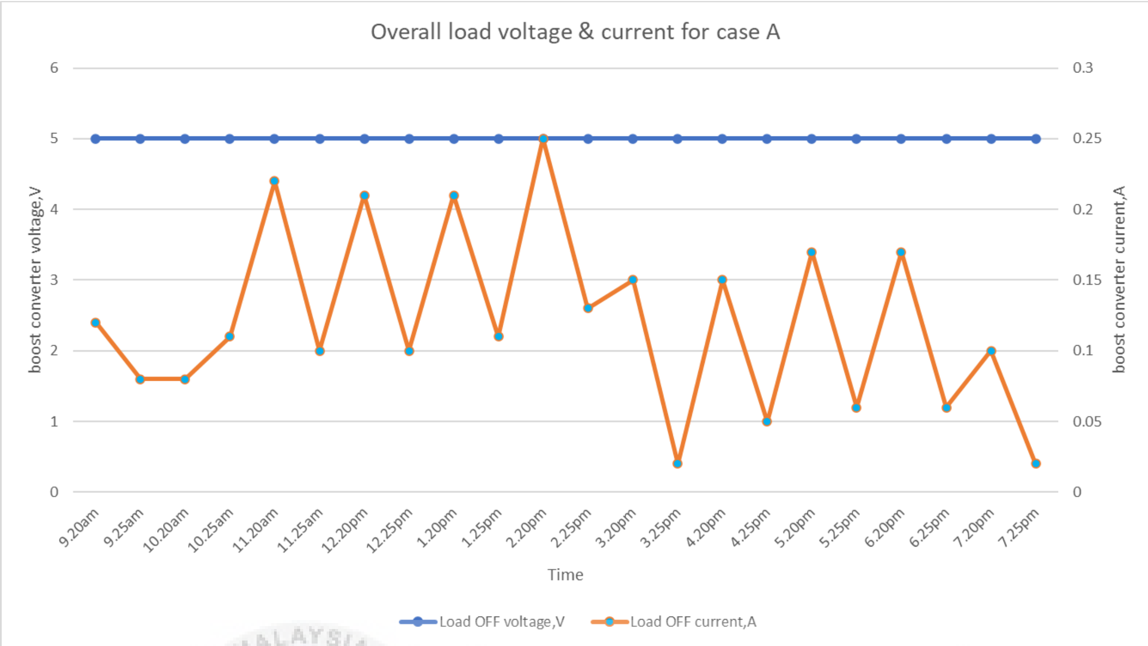


Figure 4.8 Output (overall load) voltage and current graph for Case A

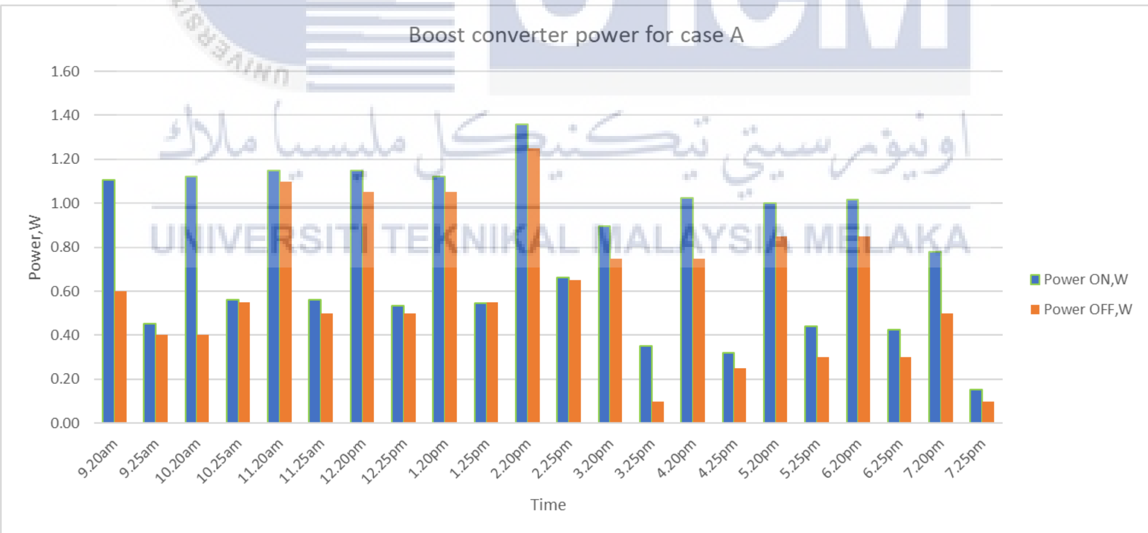


Figure 4.9 Output (overall load) power graph for case A

4.2.2 Case B

The data has been divided into two distinct components: the input and the output where data is gathered at 30-minute intervals to assess the capacity of the micro hydro turbine's generated voltage and current to recharge the system's battery. Additionally, the system is configured to deactivate the relay for a duration of 12 hours, which corresponds to the rest mode of the water pump. A half-opening microhydro turbine has been fed tap water to imitate the way it would work if it were collcting rainwater from gutter system in order to achieve a consistent water flow and a more stable current.

4.2.2.1 Input data for Case B

The input data that was gathered in a successful manner for the case B experiment, which lasted from 4:20 pm to 7:50 pm at 9/12/2023, is presented in Table 4.4.

Table 4.4 Input data (micro-hydro turbine) for case A experiment

Time	Turbine voltage,V	Turbine current,A	Power,W
4.20pm	11.2	0.04	0.448
4.50pm	11.2	0.03	0.336
5.20pm	11.2	0.04	0.448
5.50pm	11.1	0.03	0.333
6.20pm	11.3	0.02	0.226
6.50pm	11.3	0.04	0.452
7.20pm	11.3	0.03	0.339
7.50pm	11.2	0.02	0.224

Figure 4.10 and Figure 4.11 present an illustration of the periodic evolution of voltage and current flow for a system that is powered by energy obtained from a micro hydro turbine. This illustration is provided for the purpose of demonstrating how the system is powered. While the voltage is pretty consistent, with just slight fluctuations around 11.2

volts, the current swings significantly, reaching a maximum of around 0.04 amperes. But the voltage remains relatively stable. The output of the micro hydro turbine is very stable, with certain fluctuations that are to be anticipated and which most likely correspond to variations in the amount of water flow or the load demands. All things considered, the data points to the existence of a micro hydro turbine that is operational and makes a contribution to the charging system. These variances are within a range that is considered to be acceptable for a system that is meant to charge an 18650 lithium-ion battery by harnessing the power of a solar charge controller and supplementing it with a micro hydro turbine that operates at 12 volts and 2.65 watts.

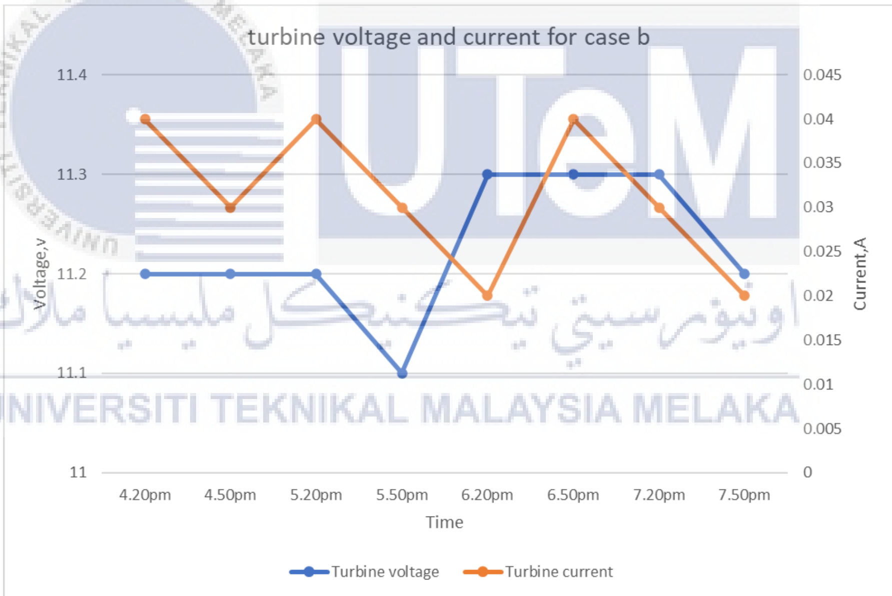


Figure 4.10 Input voltage and current graph for Case B

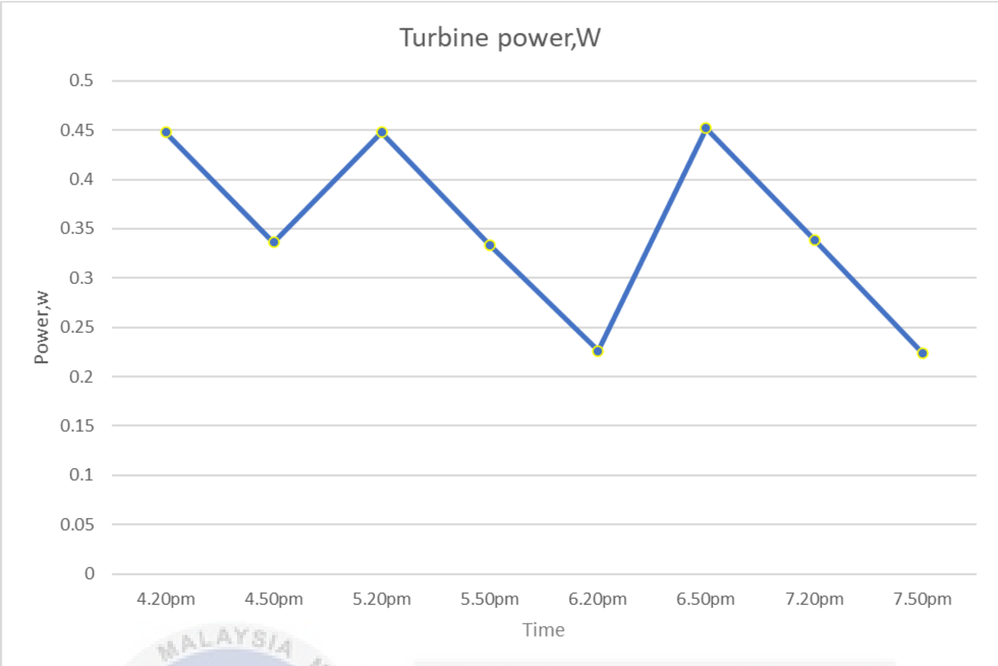


Figure 4.11 Input power graph for Case B

4.2.2.2 Output data analysis for Case B

The output data has been gathered satisfactorily for the Case B. The data depicted in Table 4.5 and table 4.6 illustrates an output analysis experiment that spanned the time period from 4:20 in morning time to 7:50 in the evening.

Table 4.5 Output data (battery) for Case B experiment

Time	Battery voltage,V	Battery current,A	Power,W	Mode charge and discharge
4.20pm	3.2	0.02	0.064	Charge
4.50pm	3.3	0.02	0.066	Charge
5.20pm	3.3	0.02	0.066	Charge
5.50pm	3.3	0.01	0.033	Charge
6.20pm	3.3	0.01	0.033	Charge
6.50pm	3.3	0.01	0.033	Charge
7.20pm	3.3	0.02	0.066	Charge
7.50pm	3.4	0.01	0.034	Charge

Table 4.6 Output data (boost converter) for Case B experiment

Time	Load ON voltage,V	Load ON current,A	Power ON,W	Load OFF voltage,V	Load OFF current,V	Power OFF,W
4.20pm	3.2	0.07	0.224	4.8	0.03	0.144
4.50pm	3.3	0.05	0.165	5	0.02	0.1
5.20pm	3.2	0.05	0.16	4.8	0.03	0.144
5.50pm	3.2	0.06	0.192	4.8	0.04	0.192
6.20pm	3.2	0.05	0.16	4.8	0.03	0.144
6.50pm	3.2	0.05	0.16	4.8	0.02	0.096
7.20pm	3.2	0.06	0.192	4.8	0.03	0.144
7.50pm	3.3	0.05	0.165	4.9	0.02	0.098

For a system enabled by a boost converter and battery, the power trends and periodic progression of voltage and current are illustrated in Figures 4.12, 4.13, 4.14, and 4.15. In two and a half hours, the battery voltage rises from 3.2 volts to 3.4 volts due to the power supplied by the micro hydro turbine. The voltage rise from 3.2 volts, the minimum voltage at which the battery can function to power the waterpump, to 3.4 volts during the recharging process, signifies the occurrence of recharging. By means of the piped water supply, the turbine voltage is maintained in service. It is customary to detect fully discharged lithium-ion batteries at a potential of 3.0 volts, subsequent to which they have been charged to 4.2 volts. If the battery consistently performs at or near this lower threshold, it could potentially signify that it is nearing its discharge limit or is not fully charged. Fluctuations in the flowrate of potable water induce voltage and current increases and decreases. Between 4.8 and 5 volts, the voltage supplied by the boost converter remains relatively constant, indicating that the boost converter consistently delivers power to the load. The current demonstrates a greater degree of variability, spanning an approximate range of 0.045 to 0.07 amperes. The observed variations in current may be attributed to fluctuations in either the load or the boost converter's efficiency. Considering the system's design to operate the water pump independently, devoid of any external power source or adequate current supply, its maintenance can be efficiently accomplished by simply recharging the battery.

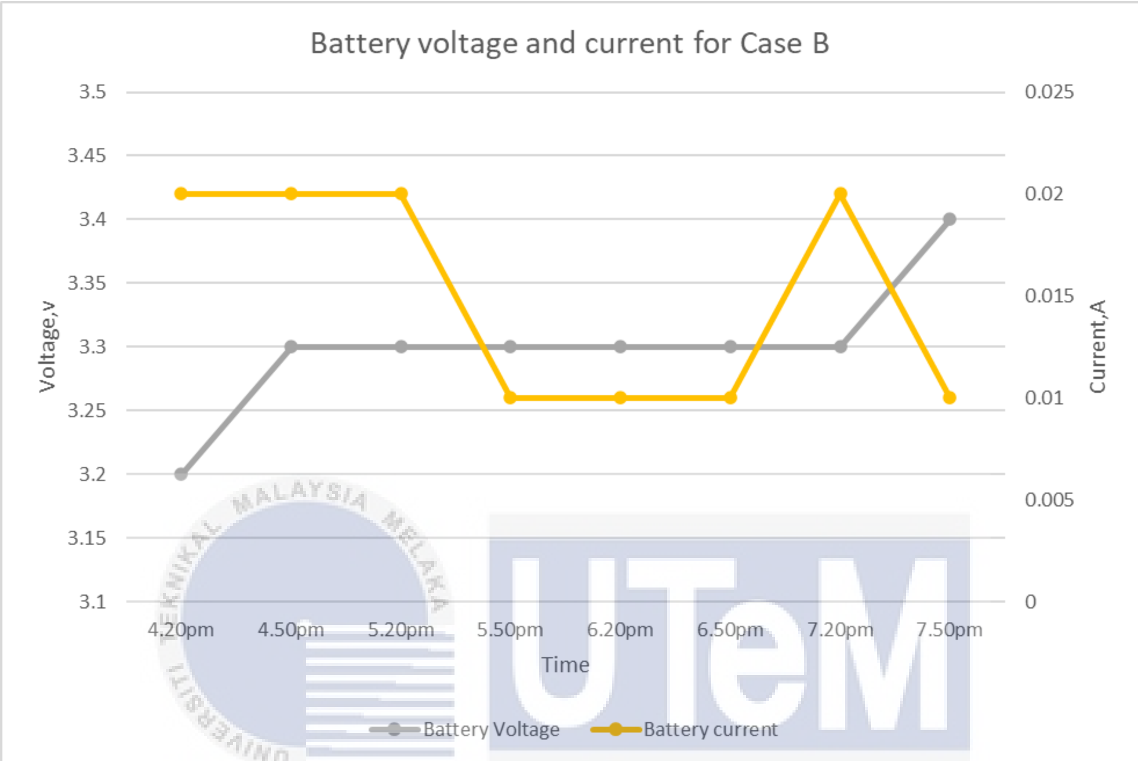


Figure 4.12 Output (battery) voltage and current graph for Case B

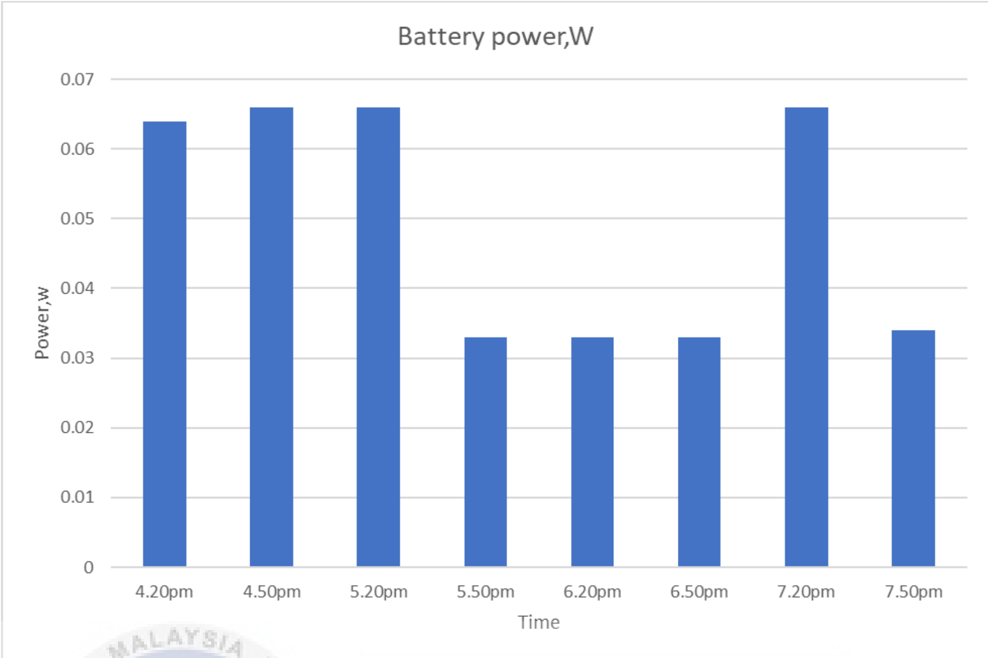


Figure 4.13 Output (battery) power graph for Case B

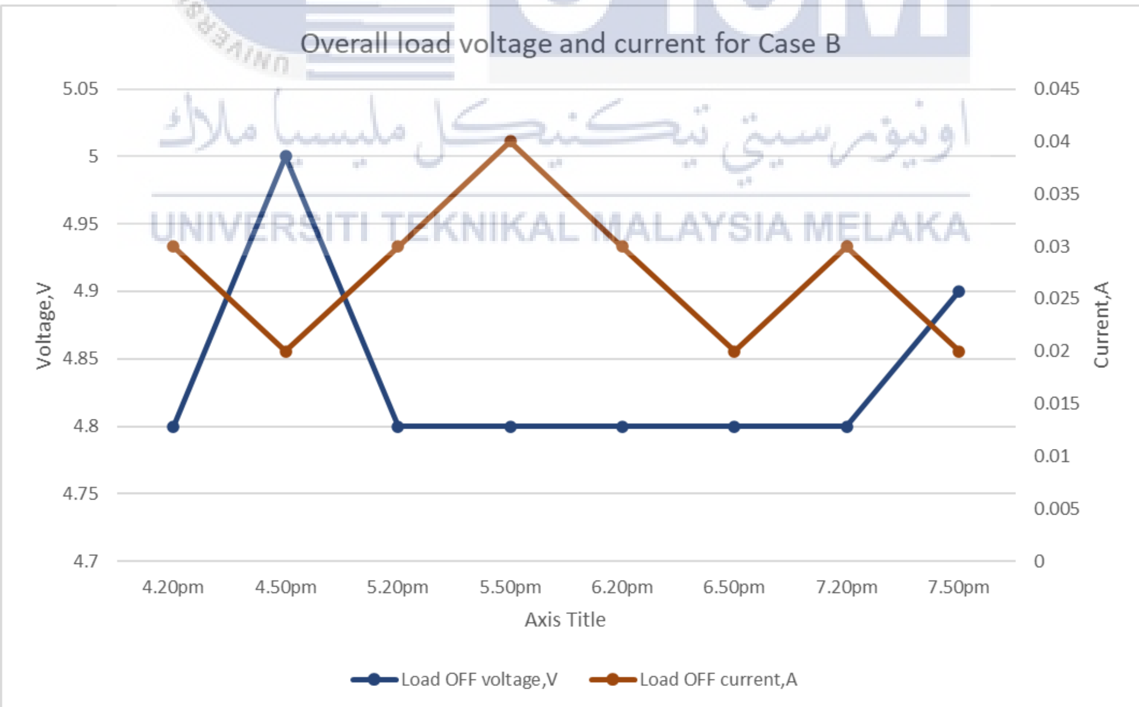


Figure 4.14 Output (overall load) voltage and current graph for Case B

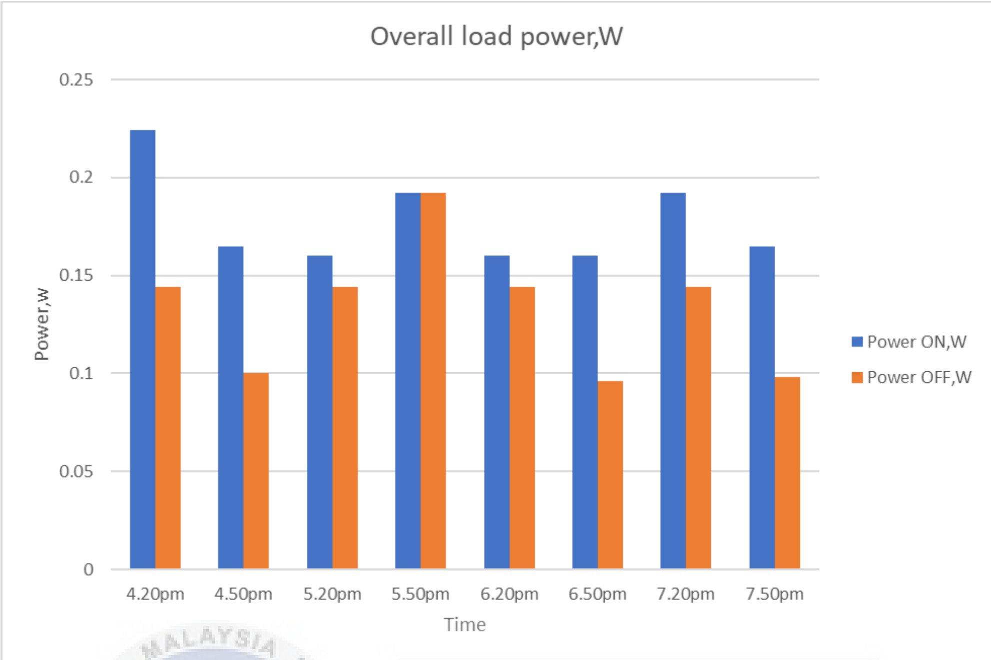


Figure 4.15 Output (overall load) power graph for Case B

4.2.3 Case C

The data has been divided into two distinct components: the input and the output where . In order to evaluate the voltage and current capabilities of the solar panels and micro-hydro turbine utilised for battery recharging within the system, data is gathered at 10-minute intervals. A diode is connected to the positive wire of both the solar panel and the microhydro turbine in order to prevent current from flowing between the two sources. Running water has been supplied with the semi-opening to microhydro turbine in order to maintain a constant water flow and a more stable current, while the solar panel remains illuminated continuously in converting the panel's energy.

4.2.3.1 Input data for Case C

The input data obtained for the Case C experiment, which was conducted between 11.35 am and 2.35 pm at 23/12/2023, is displayed in Table 4.7.

Table 4.7 Input data (solar + micro-hydro turbine) for Case C experiment

Time	Solar+turbine voltage,V	Solar+turbine current,A	Power,W
11.35pm	12.6	0.16	2.016
11.45pm	12.6	0.12	1.512
12.05pm	12.6	0.1	1.26
12.30pm	12.2	0.14	1.708
12.35pm	12.2	0.08	0.976
1.05pm	12.2	0.08	0.976
1.30pm	12.3	0.13	1.599
1.35pm	12.2	0.01	0.122
2.05pm	11.2	0.1	1.12
2.30pm	12.3	0.13	1.599
2.35pm	12.2	0.02	0.244

Figure 4.16 illustrates the linear change in current, voltage, and Figure 4.17 shows power flow for a system that is powered by a solar panel and a microhydro turbine, respectively. The document provides voltage and current data for case C, which represents a hybrid energy system that integrates micro hydro turbines and solar power. The minor variation in voltage between 12.2 and 12.6 volts produced by this combination demonstrates the stability of the hybrid system's ability to sustain a constant voltage. Conversely, the current demonstrates considerable fluctuation, characterised by abrupt surges and valleys that could potentially be ascribed to the fluctuating outputs of the solar and micro-hydro turbine sources or to alterations in the connected load's demand. The power graph exhibits a comparable trend, which signifies the direct correlation between power and current within an electrical system (with power being calculated as the product of current and voltage). The minimum power is approximately one watt, while the maximum power is approximately two

watts. The observed discrepancies in power output indicate that the energy production from the micro hydro and solar sources is not consistently stable. This may be attributed to environmental variables such as cloud cover that impact the solar output or variations in water flow that affect the micro turbine.

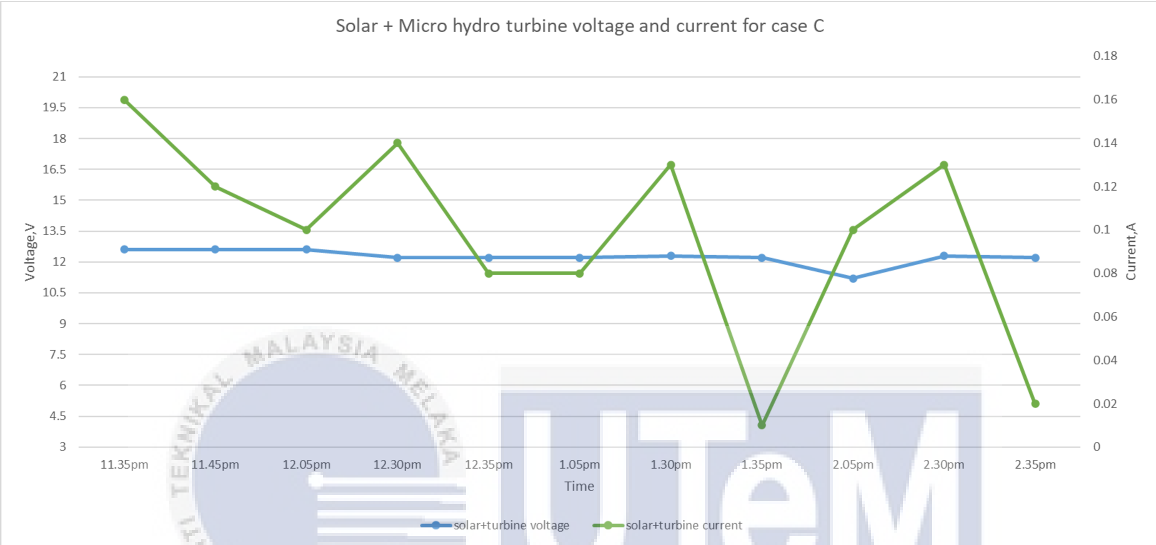


Figure 4.16 Input voltage and current graph for Case C

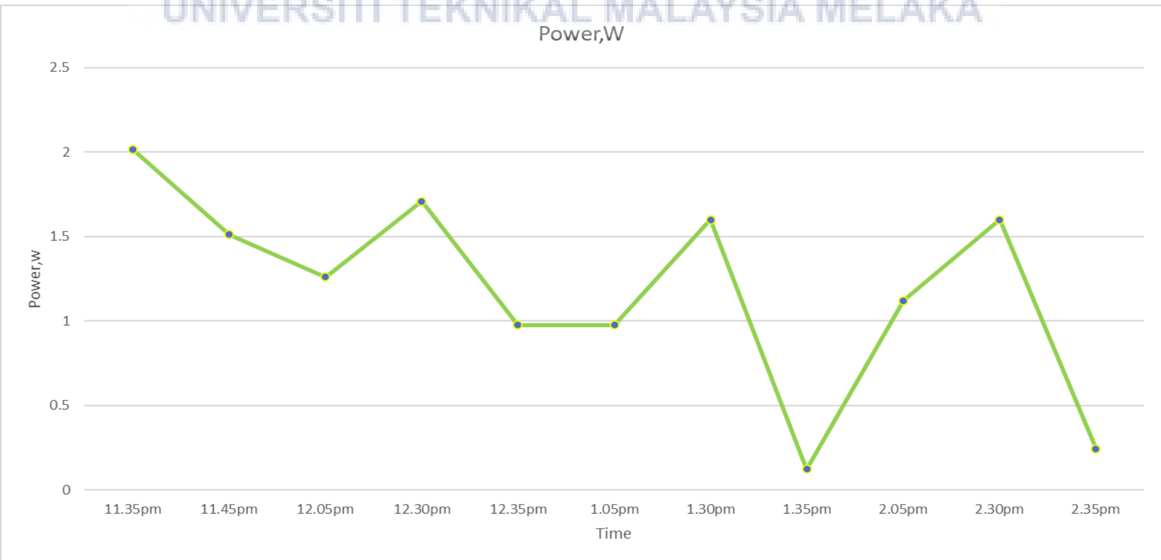


Figure 4.17 Input power graph for Case C

4.2.3.2 Output data analysis for Case C

The output data has been gathered satisfactorily for the Case C. The data depicted in Table 4.8 and table 4.9 illustrates an output analysis experiment that spanned the time period from 11.35 in morning time to 2.35 pm in the evening.

Table 4.8 Output data (battery) for Case C experiment

Time	Battery voltage,V	Battery current,A	Power,W	Mode charge and discharge
11.35pm	4.1	0.24	0.984	Charge
11.45pm	4.1	0.17	0.697	Charge
12.05pm	4.1	0.14	0.574	Charge
12.30pm	4.1	0.09	0.369	Charge
12.35pm	4.1	0.08	0.328	Charge
1.05pm	4.1	0.08	0.328	Charge
1.30pm	4.1	0.09	0.369	Charge
1.35pm	4	-0.09	-0.36	Discharge
2.05pm	4.1	0.06	0.246	Charge
2.30pm	4.1	0.1	0.41	Charge
2.35pm	4	-0.08	-0.32	Discharge

Table 4.9 Output data (overall load) for Case C experiment

Time	Load ON voltage,V	Load ON current,A	Power ON,W	Load OFF voltage,V	Load OFF current,A	Power OFF,W
11.35pm	4.1	0.11	0.451	5	0.07	0.35
11.45pm	4.1	0.08	0.328	5	0.05	0.25
12.05pm	4.1	0.1	0.41	5	0.05	0.25
12.30pm	4	0.23	0.92	5	0.15	0.75
12.35pm	4.1	0.1	0.41	5	0.06	0.3
1.05pm	4.1	0.1	0.41	5	0.06	0.3
1.30pm	4	0.24	0.96	5	0.16	0.8
1.35pm	3.9	0.09	0.351	5	0.07	0.35
2.05pm	4	0.11	0.44	5	0.07	0.35
2.30pm	4	0.23	0.92	5	0.15	0.75
2.35pm	3.9	0.1	0.39	5	0.05	0.25

The power trends as well as the periodic progression of voltage and current are depicted in Figures 4.18, 4.19, 4.20, and 4.21 for a system powered by a battery and boost converter. A hybrid microhydro turbine and solar energy are utilised to replenish the battery voltage. It is within the expected operating range for a fully charged lithium-ion battery that the battery voltage begins at approximately 4.1 volts and stabilises near that value. Negative current signifies discharge and positive current indicates charging of the battery, as depicted on the current graph. The current values exhibit a period of maximum discharge, which is accompanied by a subsequent phase in which the battery seems to be regenerating. The microhydro turbine becomes the exclusive provider of continuous voltage once the solar energy decreases. Voltage and current of the turbine are ensured by the continuous flow of water through the pipes. Fluctuations in voltage are brought about by variations in the flowrate of water intended for consumption. The boost converter shows a consistent output voltage, which is essential for sensitive electronic devices, is indicated by the boost converter voltage remaining relatively stable at approximately 5 volts with minor fluctuations. Alterations in the load or the efficacy of the boost conversion process may account for the substantial fluctuations in the current. Power is the product of current and voltage, so it is not surprising that the power graph exhibits a distinct correlation with current. Moments of increased load demand or boost converter efficiency are probable causes for the presence of distinct peaks in power, which climax at approximately 1 watt. System maintenance is readily achievable through battery replenishment, given the system's design prioritises water pump management without requiring an external power source or sufficient current.

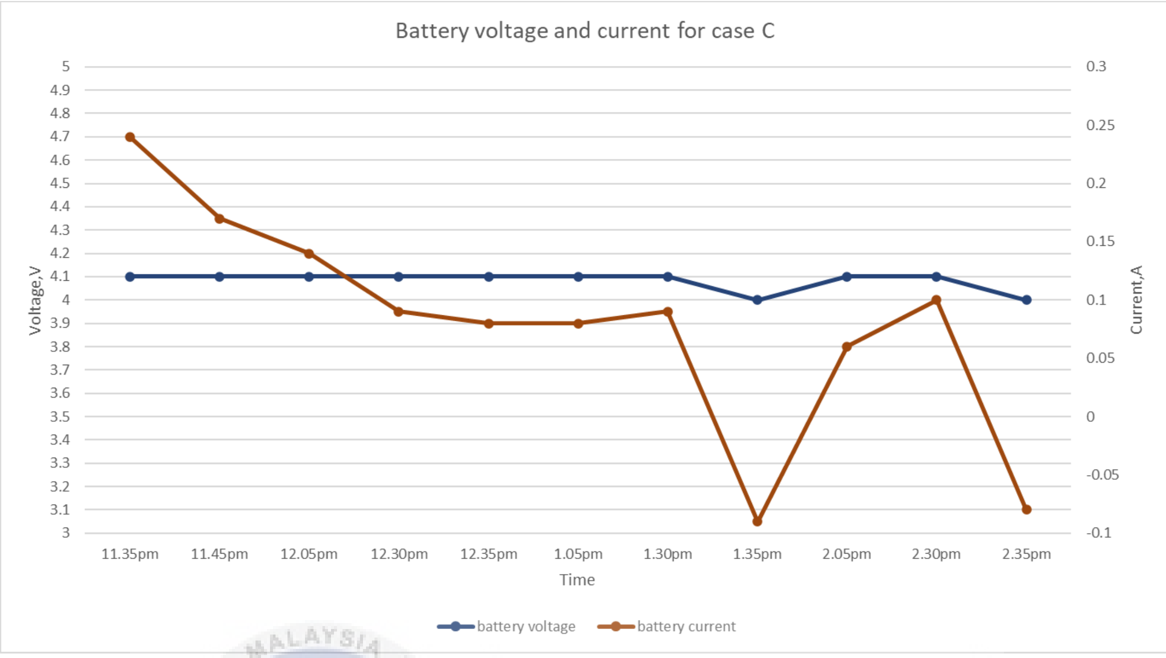


Figure 4.18 Output (battery) voltage and current graph for Case C

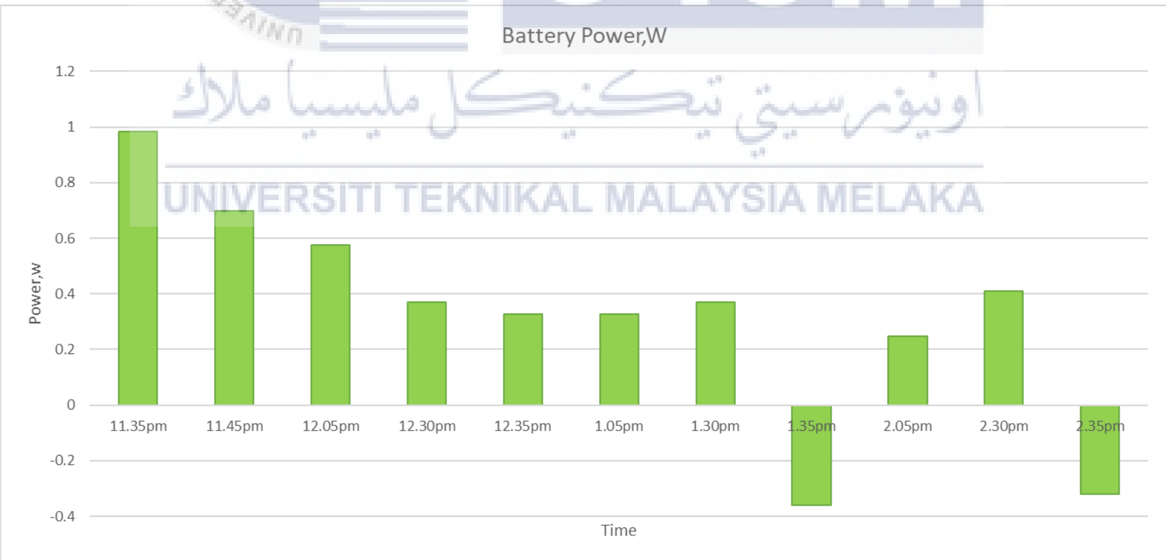


Figure 4.19 Output (battery) power graph for Case C

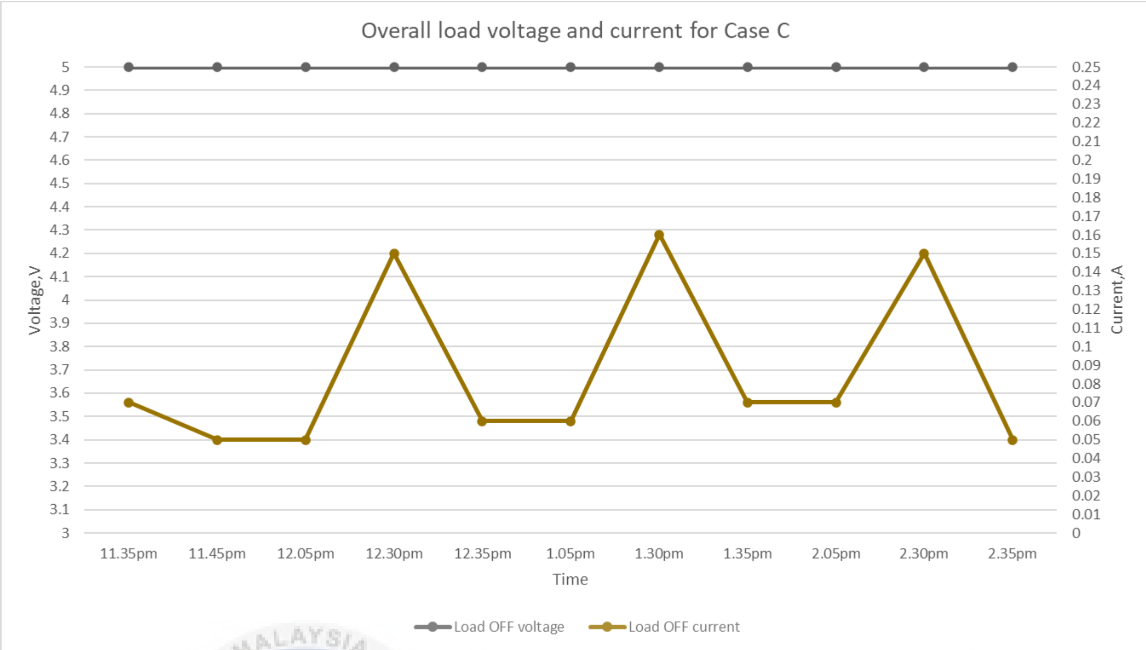


Figure 4.20 Output (overall load) voltage and current graph for Case C

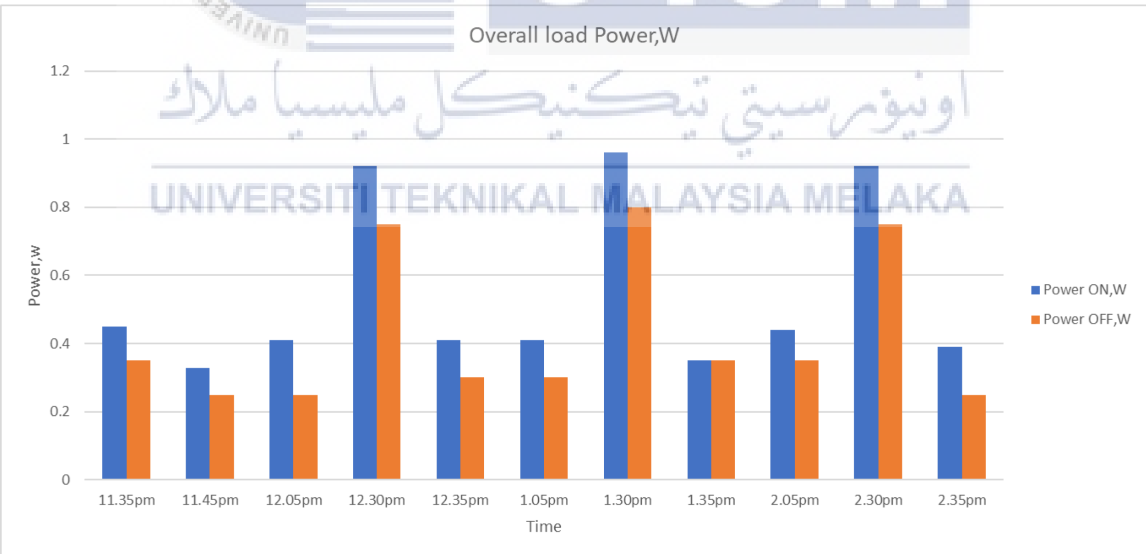


Figure 4.21 Output (overall load) power graph for Case C

4.3 Comparison of battery charging and discharging for each case

This section provides an explanation of the battery charge and discharging processes for each of the examined cases, namely case A, case B, and case C. Case A demonstrates a moderate equilibrium between input and output energy, as evidenced by its mean charging power of 0.462 kW and mean discharging power of -0.18 kW. At 75% of the charge to discharge percentage signifies that the process of charging is more prevalent than that of discharging. Although charge occurs more frequently, the notable discharging currents indicate the possibility of energy dissipation during the power output phases. The voltage stability of the device remains above 3.8 V with only minimal fluctuations, indicating a respectable capacity for energy retention. Over time, however, the increased depletion rates may have an adverse effect on the battery's health.

Case B demonstrates a steady but feeble charging procedure, characterised by a progressive surge in voltage from 3.2 V to 3.4 V and an average charging output of 0.049 kW. A significant lack of discharge is observed, suggesting that the battery receives an ongoing supply of energy, albeit at a diminished level of intensity in comparison to other instances. The high voltage stability, as evidenced by the 0.053 V standard deviation, signifies a charge that remains constant without any variability. This implies that although the turbine delivers a consistent and dependable charge, its power output might be inadequate for demanding applications. However, it might be well-suited for situations that necessitate a steady and low-power supply.

Case C illustrates an energy system that is in a state of equilibrium, as evidenced by its high charge to discharge percentage of 81.8%, which signifies that charging operations prevail over discharging ones. The mean charging power is consistently high at 0.478 kW, whereas the mean discharging power is comparatively diminished at -0.34 kW. This results in optimal energy utilisation and reduced energy loss during the discharge process. Consistent energy storage and excellent battery health are indicated by the battery voltage's low standard deviation of 0.040V, which maintains a steady value of approximately 4.1V. In general, Case C provides a resilient charging protocol characterised by consistent voltage levels, which contributes to the extended lifespan of the battery. Table 4.10 shows the value different for each data related.

Table 4.10 Data Comparison for each case

Cases / Data	CASE A	CASE B	CASE C
Average Charging Power,kW	0.462	0.049	0.478
Average Discharging Power,kW	-0.18	0	-0.34
Charge to Discharge Percentage,%	75	0	81.8
Voltage Stability,V	0.078	0.053	0.039

Overall, Cases A and C are both appropriate for the undertaking at hand. Case A demonstrates that the solar panel can sustain an effective charging regimen on its own. In contrast, Case C not only delivers marginally greater power but also sustains an elevated charge-to-discharge ratio and enhanced voltage stability—both of which are imperative for the battery's efficient charging and extended lifespan. It appears that the hybrid system in Case C provides the highest level of performance, as it charges and discharges with greater consistency and efficiency, respectively. This signifies a system with enhanced dependability, potentially capable of managing fluctuating energy demands and supplying a more consistent energy stream to the battery. This holds significant importance, especially in the case of projects that may experience fluctuating loads or necessitate a reliable energy supply under diverse conditions.

4.4 Flowrate and volume display

This section centres on the information conveyed through the i2C LCD display, encompassing the water flow rate and the accumulated volume of water within the storage tank. The algorithms utilised to ascertain the accumulated water volume and flow rate are integrated within the software code executed on an Arduino Uno. The data is interpreted by this microcontroller, which then outputs the results onto the i2C LCD screen as shown in Figure 4.22. For determining the flow rate, the YF-S201 water flow sensor is an indispensable component. As referenced in Table 4.11 that follows, the experimental values for volume and flow rate as measured during case B of the experiment are specified. This configuration renders water utilisation and storage dynamics transparent and in real-time, which is critical for monitoring and managing water resources efficiently.

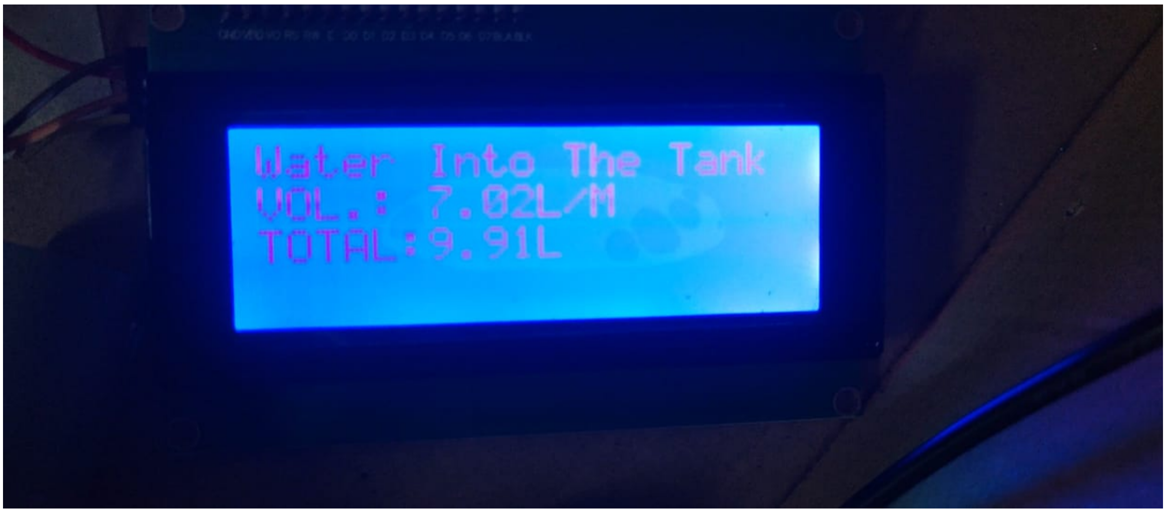


Figure 4.22 Flowrate and volume displayed on i2C LCD display

Table 4.11 Flowrate and volume data

Time	Flowrate, L/m	Volume,L
4.20pm	7.01	9.91
4.50pm	7.19	189
5.20pm	7.04	378
5.50pm	5.08	457.2
6.20pm	6.5	654.3
6.50pm	6.85	798.5
7.20pm	6.64	878.1
7.50pm	6.73	969.6

4.5 Summary

In other words, this chapter does a good job of providing a concise summary of the findings that were gained from a series of experiments that were carried out with the particular intention of accomplishing the goals that were intended. In addition, the experiment that is presently underway features the capacity to produce a specific aim achievement that is related with the project. It is recommended that the experiment that was carried out be used as a guide for any future procedures or modifications that need to be made for the undertaking.

.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As a conclusion from this entire project, based on past studies carried out by previous researchers, the creation or use of water harvesting systems is important because it is one of the ways or steps to overcome the problem of water scarcity, as informed in the literature review section. This rainwater harvesting system is still challenging to implement because more research and experts in this field are needed. Therefore, some studies have been carried focused on the energy that can be produced from the rainwater harvesting system, and the projects that have been successfully implemented regarding the rainwater harvesting system and its implementation in our country.

For that reason, a methodology has been successfully designed to produce hybrid micro-hydro and solar PV generation in a rainwater harvesting system that can act as a component to reduce the problems faced. The main components used, such as solar panels, a micro-hydro turbine, an Arduino microcontroller, and a water flow sensor, have been introduced in this project and can be easily purchased to make the project more worthwhile. The methodology of this project incorporates experiments that assess the efficacy of hybrid systems powered by microhydro turbines and solar energy. By doing so, this project can be executed and serve as a benchmark for expanding the use of rainwater harvesting systems. Positive results for this undertaking have been obtained through the conducted experiments; however, further enhancements remain feasible. In its entirety, this project was accomplished successfully at BDP PSM 2.

5.2 Future works

Future improvements can be made to the accuracy of micro-hydro and solar PV generation results as follows:

a. Using a more efficient solar charge controller to help charge the battery such as Victron Energy SmartSolar MPPT 100/30 > 30 Amp 12/24 Volt MPPT Charge Controller which is have high effciency in charging the lithium ion battery.

b. Incorporate Internet of Things (IoT) technology to augment data recording processes by methodically capturing and archiving information pertaining to micro-hydro and solar PV generation. By utilising digital advancements to streamline data administration, this methodology enables subsequent analysis and streamlines review procedures.

c. In order to improve the accuracy of microhydro and solar PV generation in precipitation harvesting systems, a comprehensive investigation into a hybrid strategy is required. This involves the implementation of dual solar charge controllers in order to efficiently and methodically accomplish the goals of the hybrid system, thereby providing a solution for the generation of energy.

d. If financial constraints are not an issue, more precise results can be achieved by incorporating external turbines or employing micro-hydro turbines to increase voltage and current generation lead to these alternatives, ITOSHI Mini Pico Hydro Generator presents itself as a feasible substitute by striking a harmonious equilibrium between capability and market price.

5.3 Potential of commercialization

The integration of micro-hydro and solar PV generation with rainwater harvesting in the hybrid system offers a substantial commercial prospect, especially in places with a lot of rain, like Malaysia. This new system can be useful for making energy, improving cities, and farming. It helps create clean energy, saves water, and makes cities better. We can earn money by letting others use the idea and working with private companies. But, it's important to be careful. We need to balance making money with helping the world with climate change. This way, the technology stays useful and available for many people. By focusing on being eco-friendly and fair, this system not only makes money but also helps the environment and communities.

REFERENCES

[1] N. H. M. Lani, Z. Yusop, and A. Syafiuddin, “A review of rainwater harvesting in Malaysia: Prospects and challenges,” *Water (Switzerland)*, vol. 10, no. 4. MDPI AG, 2018. doi: 10.3390/w10040506.

[2] M. S. Shahriar Haque, W. Al Islam, T. R. Ferdousi, S. S. Oyshee, and T. M. Tamim, “An Approach of Implementing IoT Based Rooftop Rainwater Harvesting & Monitoring,” in *Proceedings of 2021 IEEE International Conference on Robotics, Automation, Artificial-Intelligence and Internet-of-Things, RAAICON 2021*, Institute of Electrical and Electronics Engineers Inc., 2021, pp. 60–63. doi: 10.1109/RAAICON54709.2021.9929467.

[3] Universidad Autónoma de Querétaro and Institute of Electrical and Electronics Engineers, *2017 XIII International Engineering Congress (CONIIN) : Universidad Autónoma de Querétaro, Santiago de Queretáro, Mexico : from 2017-05-15 to 2017-05-19.*

[4] W. Zhou, K. Matsumoto, and M. Sawaki, “Traditional domestic rainwater harvesting systems: classification, sustainability challenges, and future perspectives,” *Journal of Asian Architecture and Building Engineering*, vol. 22, no. 2, pp. 576–588, 2023, doi: 10.1080/13467581.2022.2047979.

[5] M. Á. Zamora-Juárez, C. R. Fonseca Ortiz, V. H. Guerra-Cobián, B. M. López-Rebollar, I. Gallego Alarcón, and D. García-Pulido, “Parametric assessment of a Pelton turbine within a rainwater harvesting system for micro hydro-power generation in urban zones,” *Energy for Sustainable Development*, vol. 73, pp. 101–115, Apr. 2023, doi: 10.1016/j.esd.2023.01.015.

[6] American Statistical Association, M. IEEE Systems, and National Institute of Standards and Technology (U.S.), *Simulation Conference (WSC), Proceedings of the 2012 Winter : date 9-12 Dec. 2012.* IEEE, 2012.

[7] Majlis Bandaraya Melaka Bersejarah (MBMB), "sistem_pengumpulan_dan_penggunaan_semula_air_hujan_spah," 2019.

[8] I. C. Juliana, M. Syahril, B. Kusuma, M. Cahyono, H. Kardhana, and W. Martokusumo, "Performance of rainwater harvesting system based on roof catchment area and storage tank capacity."

[9] M. Mirdanies, Institute of Electrical and Electronics Engineers. Indonesia Section, and Institute of Electrical and Electronics Engineers, *2015 International Conference on Sustainable Energy Engineering and Application (ICSEEA) : "Sustainable Energy for Greater Development" : proceeding : 5-7 October 2015, Aston Tropicana Hotel, Bandung, Indonesia*.

[10] V. T. Varuna Mithra, R. Sharmila, and M. V. S. S. Giridhar, "DEVELOPMENT OF HYBRID POWER GENERATION MODEL USING RAIN WATER, SOLAR AND WIND."

[11] Hamzah Ahmad, "MICRO-HYDRO POWER," 2014.

[12] M. Casini, "Harvesting energy from in-pipe hydro systems at urban and building scale," *International Journal of Smart Grid and Clean Energy*, doi: 10.12720/sgce.4.4.316-327.

[13] J. Carter, A. Rahmani, M. Dibaj, and M. Akrami, "Rainwater Energy Harvesting Using Micro-Turbines in Downpipes," *Energies (Basel)*, vol. 16, no. 4, Feb. 2023, doi: 10.3390/en16041660.

[14] N. J. Kumbhar, P. Pravin, Z. Aditya, S. Rohit, and P. Sonam, "Design and implementation of micro hydro turbine for power generation and its application," *International Research Journal of Engineering and Technology*, 2016, [Online]. Available: www.irjet.net

[15] M. S. Aziz, M. A. Khan, H. Jamil, F. Jamil, A. Chursin, and D. H. Kim, "Design and analysis of in-pipe hydro-turbine for an optimized nearly zero energy building," *Sensors*, vol. 21, no. 23, Dec. 2021, doi: 10.3390/s21238154.

[16] G. Singh, "Gravitation water vortex power generator in domestic plastic water tank integrated with RO + UV Water purifier (Drinking Grade)," 2017.

[17] D. K. Kumar V and A. Professor, "Bangalore Technological Institute, India) 3(Mechanical engineering," 2020. [Online]. Available: www.ijlera.com

[18] F. Viola, P. Romano, R. Miceli, G. Acciari, and C. Spataro, "Piezoelectric model of rainfall energy harvester," 2014.

[19] Z. A. Halim, A. T. Din, E. M. Tokit, and M. A. M. Rosli, "Development of Rainwater Harvesting System for Sekolah Menengah Kebangsaan Iskandar Syah Melaka," in *IOP Conference Series: Earth and Environmental Science*, Institute of Physics Publishing, Jul. 2019. doi: 10.1088/1755-1315/268/1/012024.

[20] K. P. Rani, K. Srija, A. Jyothianvitha, M. Ashasri, I. Mamatha, and G. Rajesh, "Rain water harvesting for smart water management using IoT," in *Proceedings - 5th International Conference on Intelligent Computing and Control Systems, ICICCS 2021*, Institute of Electrical and Electronics Engineers Inc., May 2021, pp. 475–478. doi: 10.1109/ICICCS51141.2021.9432365.

[21] G. Verma, S. Gupta, and R. Gupta, "IoT Based Technique for Household Rainwater Harvesting," in *2020 Global Conference on Wireless and Optical Technologies, GCWOT 2020*, Institute of Electrical and Electronics Engineers Inc., Oct. 2020. doi: 10.1109/GCWOT49901.2020.9391634.

[22] H. A. Zabidi, H. W. Goh, C. K. Chang, N. W. Chan, and N. A. Zakaria, “A Review of Roof and Pond Rainwater Harvesting System: the Design, Performance and Way Forward,” 2020, doi: 10.20944/preprints202009.0549.v1.

[23] W. Sie Woo, S. A. Ong Ling, L. Che Chien, and P. Julini Goel, “Development of Micro Solar-Hydro Power Generation System for Rural Area Under Tropical Climate (Pembangunan Sistem Penjanaan Tenaga Mikro Solar-Hidro untuk Kawasan Pendalaman Cuaca Tropikal),” 2021.