Faculty of Electrical and Electronic Engineering Technology

THE DEVELOPMENT OF PUMPED STORAGE HYDROPOWER USING SMALL SCALE PROTOTYPE

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Bachelor of Electrical Engineering Technology with Honours

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THE DEVELOPMENT OF PUMPED STORAGE HYDROPOWER USING SMALL SCALE PROTOTYPE

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in partial fulfillment of the requirements for the degree of
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DECLARATION

I declare that this project report entitled "The Development Of Pumped Storage Hydropower By Using Small Scale Prototype" 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 :

Student Name : NURUL SHAZANA BINTI MAT SOBRI

Date : 12 JANUARI 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	:	DR.MOHD BADRIL BIN NOR SHAH
Date	:	12 JANUARI 2023

DEDICATION

I appreciate, respect, and sincerely thank my parents for their love, support, encouragement, and sacrifice throughout my life. I would not have been able to get here without sacrifice and support. The greatest thanks goes out to my siblings as well, who have always helped me out and given me advice in all I do in life. They have also served as my source of motivation and have always given me their moral, spiritual, emotional, and financial support. I would like to extend my sincere gratitude to all of the lecturers, especially my supervisor Dr. Mohd Badril Bin Nor Shah, my academic advisor, and the advisor of the fe^{3}tsa club who have helped me learn and improve throughout my research findings and ensured that this Bachelor's Final Project has been completed successfully. I would like to thank all my colleagues who have always been with me throughout this challenging semester and helped me during this project. I hope all their support and encouragement will help me make this project a success.

ABSTRACT

Pumped hydroelectric energy storage is a form of hydroelectric energy storage that is used for load balancing in electric power plants. Water pumped from a lower elevation reservoir to a higher elevation is used to store energy in the form of gravitational potential energy. Using pumped-storage hydroelectricity, energy from instantaneous sources (such as solar and wind) and other renewables energy, as well as excess power from continuous base-load sources (such as nuclear or coal), may be stored for periods of higher demand. When compared to usual hydroelectric dams of comparable power output, pumped storage reservoirs are quite small, and production times are frequently shorter than half a day. In this project, a small scale of pumped storage hydropower will be developed by using two small water tanks, and a solar panel will be used as a renewable energy source that will power an electrical pump to deliver water from lower elevation tank to the higher elevation tank. The water inside higher elevation tank will flow back to lower elevation tank and the same time will move the water turbine generator to produce electrical energy. It is found that the developed small scaled pumped storage hydropower prototype is not efficient to battery-based solar charging system in term of output power and consistency.

ABSTRAK

Penyimpan tenaga hidroelektrik yang dipam adalah satu bentuk simpanan tenaga hidroelektrik yang digunakan untuk mengimbangi beban dalam loji kuasa elektrik. Air yang dipam dari takungan ketinggian yang lebih rendah ke tempat yang lebih tinggi digunakan untuk menyimpan tenaga dalam bentuk tenaga keupayaan graviti. Menggunakan pam simpanan hidroelektrik, tenaga daripada sumber terputus-putus (seperti suria dan angin) dan tenaga boleh diperbaharui lain, serta lebihan kuasa daripada sumber beban asas berterusan (seperti nuklear atau arang batu), boleh disimpan untuk tempoh permintaan yang lebih tinggi. Jika dibandingkan dengan empangan hidroelektrik biasa dengan keluaran kuasa yang setanding, takungan simpanan yang dipam adalah agak kecil, dan masa pengeluaran selalunya lebih pendek daripada setengah hari. Dalam projek ini, skala kecil kuasa hidro penyimpanan yang dipam akan dibangunkan dengan menggunakan dua tangki air kecil, dan panel solar akan digunakan sebagai sumber tenaga boleh diperbaharui yang akan menguasai pam elektrik untuk menyampaikan air dari tangki ketinggian yang lebih rendah ke ketinggian yang lebih tinggi tangki. Air di dalam tangki ketinggian yang lebih tinggi akan mengalir kembali ke tangki ketinggian yang lebih rendah dan masa yang sama akan menggerakkan penjana turbin air untuk menghasilkan tenaga elektrik. Adalah didapati penyimpanan tenaga hidroelektrik yang dipam berskala kecil yang dibangunkan adalah tidak cekap berbanding dengan sistem pengecasan solar berasaskan bateri dari segi kuasa keluaran dan ketekalannya.

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Next, I'd like to thank my supervisor, Dr. Mohd Badril Bin Nor Shah of the Faculty of Electrical and Electronics Engineering Technology, for his invaluable guidance, support, and encouragement in completing this thesis. I'd be lost without him. Thank you for your encouragement and support.

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LIST OF SYMBOLS

%	-	Percent
±	-	Plus minus
Ω	-	Ohms
≥	-	Greater than or equal to
℃	-	Degree Celsius
ℓ	-	Litre

LIST OF ABBREVIATIONS

PHES	-	Pump hydroelectric energy storage
TSO	-	Transmission system operator
V	-	Voltage
PSH	-	Pumped storage hydropower
DC	-	Direct current
AC	-	Alternating current
TF	-	Thin film
CdTe	-	Cadmium telluride
a-Si	-	Amorphous silicon
CIGS	-	Copper indium gallium
R&D	-	Research and development
PV	-	Photovoltaics
Wh	-	Watt-hour
Ah	-	Ampere hours
LCD	-	Liquid crystal display
Wi-Fi	-	Wireless Fidelity
MPPT	-	Maximum power point tracking
PWM	-	Pulse Width Modulation
Hz	-	Hertz
I/O	-	Input/Output
USB	-	Universal serial bus
g	-	Grams
mpa	-	Mili Pascal
W	-	Watt
EVD	-	Electronic visual display
IoT	-	Internet of things
LED	-	Light-emitting diode

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Pumped hydropower storage is a form of hydropower storage in use in hydroelectricity for load balancing. Gravitational potential energy is stored in water pushed from a lower elevation reservoir to a higher elevation reservoir. Energy via renewable sources (such as wind and solar) and other renewables, and also excess power from continuous base-load sources (including such coal or nuclear), may be preserved for periods when demand is higher using pumped-storage hydroelectricity. Pumped storage reservoirs is small in comparison to ordinary hydro power of equivalent power generation, and producing periods are usually less than half a day.

Next, due to the power system's instantaneous nature, constant monitoring and changes are necessary to ensure that power generation matches power consumption, which may be catered by including power storage into the load. Energy storage is especially important for the renewable energy sector since it decreases output voltage and frequency fluctuations, therefore enhancing the quality of power generation. It also prevents the wastage of a tiny quantity of unneeded electrical energy. Furthermore, battery is the most common kind of energy storage for mini-grid solar energy storage systems, but it is expensive, harmful to the environment, and requires frequent maintenance.

This project compares the feasibility and efficacy of a small-scale pump storage hydropower prototype to a battery-based solar charging system that uses a sealed lead acid battery to monitor the voltage and current drawn by the load, taking into consideration the limitations of lead-acid battery systems and the success of pumped storage in large facilities.

1.2 Problem Statement

The most widely used of the existing techniques for storing energy on a large scale is pumped hydroelectric energy storage (PHES). Because of the large amount of potential energy that can be stored in pumped storage reservoirs, the energy conversion efficiency of the full cycle, the cost per power unit, and the ability of these plants to the Transmission System Operator (TSO) in short-term operation, PHES is the most appealing option for large-scale energy storage. Hydropower made for the greatest percentage of the world total. Because of the instantaneous nature of the electrical system, continuous monitoring and modifications are required to ensure that power output and demand are balanced, which may be catered by incorporating energy storage into the grid. since it decreases output voltage and frequency fluctuations, improving the quality of power generation. PHES also avoids the remaining balance of the electrical energy created from going to waste.

1.3 Project Objective

This project's major purpose is to develop an efficient and structured mechanism for determining with tolerable accuracy, the effectiveness of the developed pumped storage hydropower prototype will be compared to a battery-based solar charging system. Specifically, the objectives are as follows:

a) To develop Arduino based circuit that measure load current and load voltage.

b) To design a small scale prototype pumped storage hydropower using solar-powered system.

c) To compare the efficacy of pumped storage hydropower prototype with battery-based solar system.

1.4 Scope of Project

The scope of the project is defined as follows:

a) Circuit Design

- The system is made up of solar-powered pumped storage hydropower and a battery-based solar charging system that can display output readings for each load for small scale prototype.

b) Program Development

- To use the Arduino IDE software to write a program for an Arduino UNO microcontroller to perform measurement of load current and voltage.

c) Software Development

- To construct and the circuit connections using PROTEUS software, which can display the output for this design circuit.

d) Hardware

- Solar charging requires a sealed lead acid battery and solar charge controller then use adapter 5V to power up to the Arduino board, and pumped storage hydropower requires two tanks, a pump motor, and a 12V generator. To monitor the output differential of each load, both are connected to a voltage sensor and a current sensor.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review is a past study from a collection of academic references, such as journal articles and theses, related to a particular research subject or challenge. The researcher will utilize the literature reviews to learn about other people's practices in order to use them as guides for this project. It will allow the researcher to have a better understanding of the topic and to create or innovate new ways.

2.2 Pumped storage hydropower

Hydropower with reservoirs is a well-developed and widely used method of renewable energy storage today[1]. Potential energy is stored in water in a reservoir behind a hydroelectric power plant for a variety of time periods, from hours to years. Hydropower reservoirs are frequently multi-purpose reservoirs that also provide home and industrial water supply, agricultural irrigation, flood control, fish farming, and recreational use. By referring figure 2.1 shows a method of hydro power storage is pumped storage hydropower (PSH). It's a system that uses two storage tanks at different elevations to generate electricity as water flows from one to the other (distribution) and via a turbine. Pumping water back into top reservoir requires power as well (recharge). PSH functions similarly to a big battery in that it can store and release energy as needed. PSH is classified as either open-loop or closed-loop. A continuous hydrologic link to a body of water exists in an open-loop PSH. Reservoirs in closed-loop PSH are also not connected to the external body of water [2].

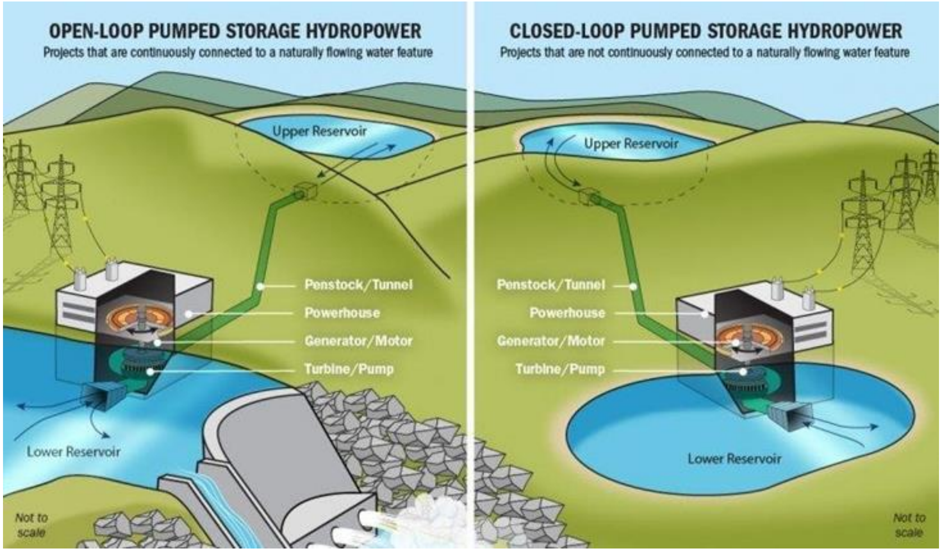

Figure 2.1 Design of pumped storage hydropower [2]

2.3 Solar power as a source of energy

Solar energy systems are already a well-established technology that is innately safer than certain potentially hazardous electricity-generating methods [3]. In addition, solar can also save costs as it is a natural and readily available source of energy. In Malaysia, there have four types of solar system that actually work such as hybrid solar, direct current solar systems, grid-connected system and off-grid residential solar system [4]. The figure 2.2 shows the differences between solar system.

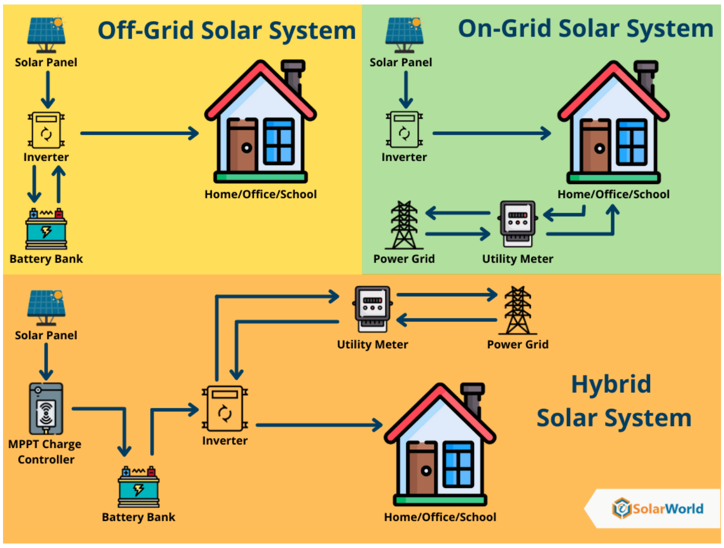

Figure 2.2 Differences between solar system [5]

Hybrid solar, often known as grid-connected solar with energy storage, is the first form of solar system. When compared to off-grid residential solar systems, this solution saves money for consumers. This is because if the battery has energy stored in it, it will use it instead of the grid's electricity. However, one disadvantage of this technology is that it is more expensive. This is due to the fact that you will need to replace the batteries on a regular basis to keep it from being worn out.

Furthermore, the most widely used system is the Grid-Connected System. It connects to the home's electrical system and the local grid. Any excess electricity is sent back to the grid. This method is excellent since it does not need much maintenance. Because it requires less equipment, the operational expenses are quite cheap. It is very efficient for a direct current solar system since it only requires one conversion, which is Direct Current, making it more effective.

Figure 2.3 shows the Off-grid power system with solar power appropriate for pumped storage hydropower prototype with battery-based solar system. In smaller DC coupled systems, a solar charge controller is used to regulate battery charging, after which the DC power is converted to AC and provided to the load through an off-grid inverter.

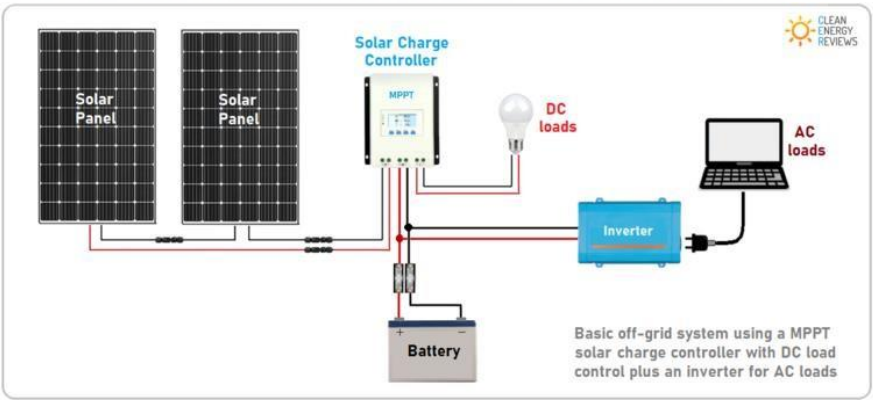

Figure 2.3 Off-grid solar power system [6]

2.4 Type of solar panel

Solar panels are an important consideration in terms of solar panel efficiency and site suitability, as well as possible financial savings and environmental benefits for the user. There have three type of solar panel which monocrystalline, polycrystalline and thin film (TF) [7].

2.4.1 Monocrystalline

Referring figure 2.4, Monocrystalline solar panels are made up of cells cut from a single crystalline silicon. When compared to polycrystalline solar panels, it is slightly more efficient. As a result, monocrystalline panels have a high power output. It's also the smallest and lasts the longest of the other panels.

Figure 2.4 Monocrystalline solar panel [7]

2.4.2 Polycrystalline

Figure 2.5 shows the polycrystalline solar panels use the same material as monocrystalline panels, but polycrystalline are made up of multiple pieces of silicon combined together. It’s slightly less efficient, but it’s the most sustainable to produce and therefore costs less to the end user.

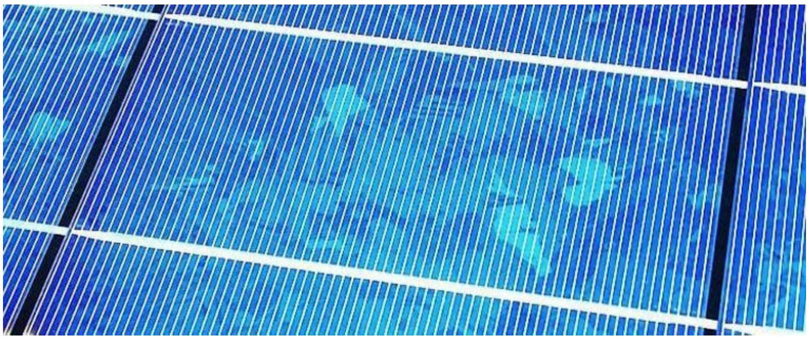

Figure 2.5 Polycrystalline solar panel [7]

2.4.3 Thin film (TF)

Thin film solar panels show in figure 2.6 are built of several materials, including cadmium telluride (CdTe), amorphous silicon (a-Si), and Copper Indium Gallium Selenide (CIGS). As a consequence, these cells are 350 times thinner than monocrystalline and polycrystalline panels. This panel is lightweight and flexible, making it ideal for any roof design.

Figure 2.6 Thin film (TF) solar panel [8]

2.5 Solar Charging system

Today's R&D, including supporting technologies like smart consumer gadgets, electric cars, and smart grids, is driven by energy for one sustainable future. Batteries are required for these technologies. Solar, a cheap and clean source of energy, may help batteries overcome their energy limitations, while batteries can help with photovoltaic intermittent renewables [9]. Figure 2.7 shows the solar charging battery that the combined PV-battery system provides a small and energy-efficient PV-battery system.

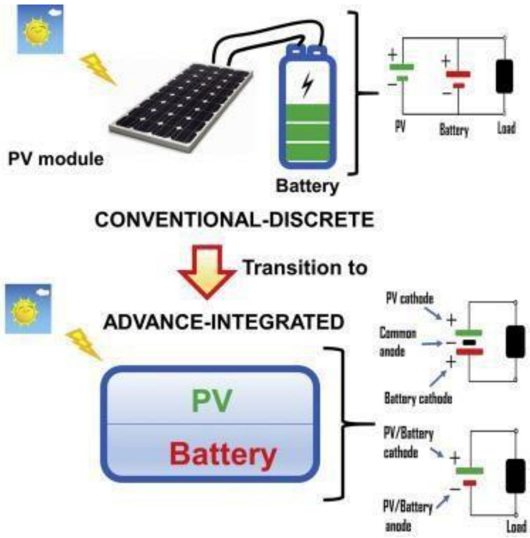

Figure 2.7 Solar charging battery [9]

Furthermore, in order to use a solar charging system, we must calculate and understand the solar design. The solar design can be determined the battery size and quantity that may be used then it can be calculated using the step below:

Step 1: Determine requirements

Step 2: Determine average daily, Wh

[AC average / inverter efficiency] + DC average

Step 3: Determine battery bank capacity, Wh

[Daily average X Days of autonomy X Multiplier] / Discharge limit

Step 4: Determine battery bank capacity, Ah

[Battery bank capacity / System voltage]

In addition, the type of battery that is suitable for this project is a sealed lead acid battery because it is cheap, safe, durable and has a wide temperature range based on table 2.1.

Table 2.1 Shows differences between lead acid, lithium-ion and sodium-ion batteries [10]

Parameters	Lead Acid Batteries	Lithium-ion Batteries	Sodium-ion Batteries
Cost	Low	High	Low
Energy Density	Low	High	Moderate/High
Safety	Moderate	Low	High
Materials	Toxic	Scarce	Earth-abundant
Cycling Stability	Moderate (high self-discharge)	High (negligible self-discharge)	High (negligible self-discharge)
Efficiency	Low (< 75%)	High (> 90%)	High (> 90%)
Temperature Range	-40 °C to 60 °C	-25 °C to 40 °C	-40 °C to 60 °C
Remarks	Mature technology; fast charging not possible	Transportation restrictions at discharged state	Less mature technology; easy transportation

2.6 Arduino Based Solar Powered Battery Charging

A solar charging system is very important because it can store solar energy and also provide electricity to devices or batteries. In [11], A low-cost parameter-measurement system for a photovoltaic power panel utilizing an Arduino microcontroller board has been developed to keep records of voltage, current, light intensity, temperature, and pressure, among other things. By referring Figure 2.8, the hardware circuit was created to connect several sensors to the Arduino board, and the resulting data was then recorded in a computer for future study.

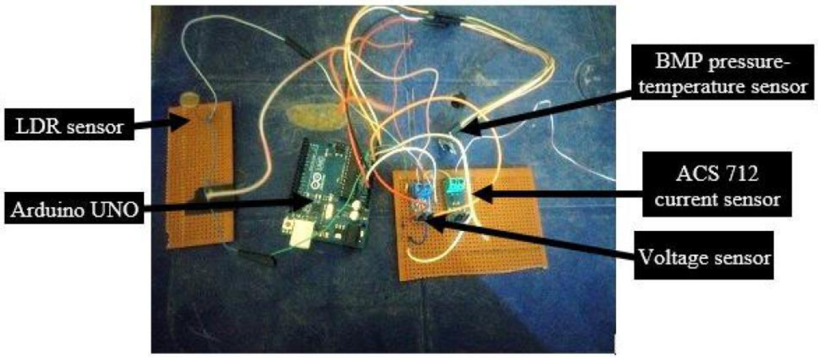

Figure 2.8 Solar PV parameter-measuring system designed [11]

Next, figure 2.9 shows the design of solar power system that design the portable device casing that easy to move [12]. This system method is to identify the device's accuracyand the Arduino-based solar power measurement system comprises panels set in a certain arrangement at a 45-degree angle to capture high-intensity solar radiation from the sun.

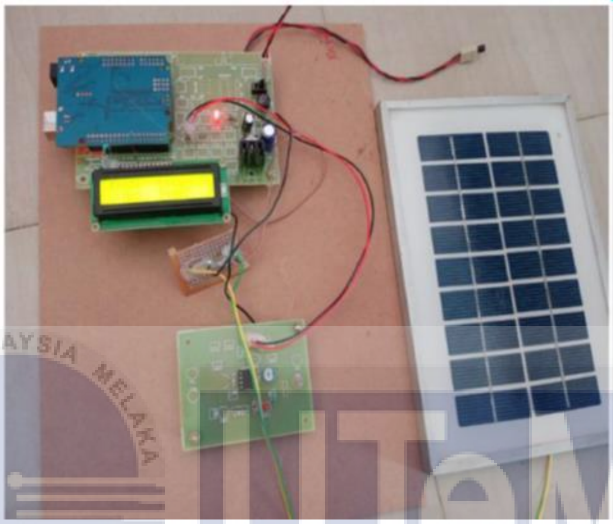

Figure 2.9 Design of solar power system [12]

In [13], A low-cost solar-powered battery charging system based on a microcontroller have been developed with LCD display and Wi-Fi module for storing and logging the data. This system was implement by using MPPT algorithms.

All of this system have many different method and application that can be observedparameters demonstrate that solar photovoltaic panel output energy generation is highly dependent on solar irradiance and temperature. To use the stored solar energy more efficiently and continuously, we need to lower the parameters and some components to reduce the cost of building the solar based charging system.

2.7 Related previous work of pumped storage hydropower

According to [14], the authors present the micro hydro power plant with dummy load based on Arduino Uno and LabVIEW by develop automatic frequency range around 51-52 Hz. Then, the output can be view in LabVIEW. For this prototype, their use Arduino Uno, L298D motor drive, ZMPT101B AC voltage sensor, ACS712 current sensor, and PWM signal. Figure 2.10 shows the Monitoring and control design of micro hydro prototype and test result with 51 Hz of frequency is shown in Table 2.2.

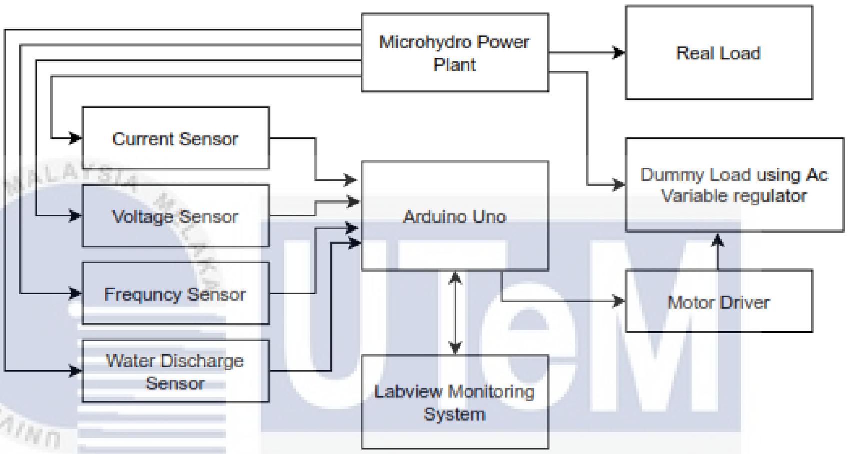

Figure 2.10 Monitoring and control design of micro hydro prototype [14]

Table 2.2 Shows test result with 51 Hz of frequency [14]

Frequency (Hz)	Voltage (V)	Current (A)
51	37,00	0,21
51	37,00	0,21
51	37,00	0,21
51	37,00	0,21
51	39,00	0,21
51	39,00	0,21
51	39,00	0,21
51	39,00	0,21
51	39,00	0,21
51	39,00	0,23
51	39,00	0,23

The work done by [15] is about optimizing self-consumption of energy and to determine the feasible self-sufficiency rate and economic performance, various solar and turbine sizes are explored. Using the solar plants to self-produce the energy required by these facilities is a cost-effective solution, a reliance on the grid to balance the imbalance between PV production and load demand is necessary. Figure 2.11 shows that the simplified schematic of PV-PHES system.

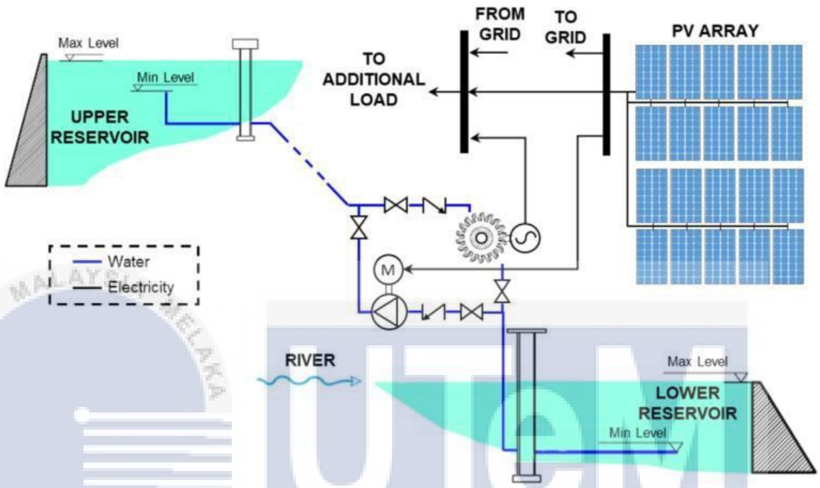

Figure 2.11 PV-PHES system schematic simplified [15]

There is a study about optimal generation schedule for hydropower plant performed in [16]. The goal of this research is to study at marginal operating costs on an hourly basis. So the method that can fulfil the maintenance cycle has applied a minimum run time limit. Lastly, research from this journal [17] studied about how to improve grid stability and encourage the use of additional intermittent renewable energy sources like wind and solar. So the method is to improve plant performance and flexibility, advancements in turbine design are essential. Figure 2.12 below shows the concept of solar PV-powered pumped hydroelectric storage (PHES) system.

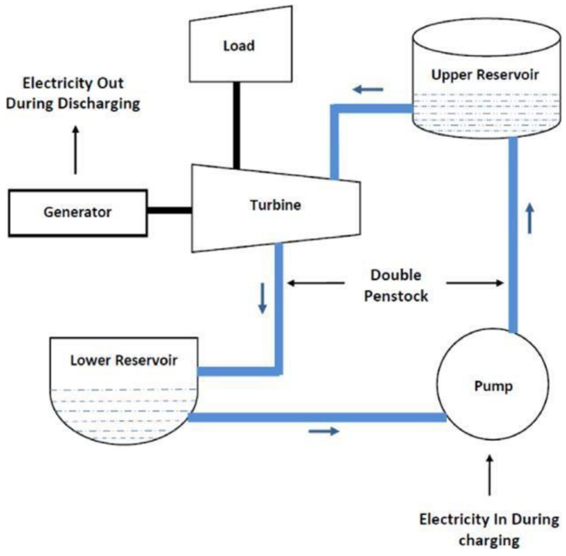

Figure 2.12 Solar PV-powered pumped hydroelectric storage (PHES) system [17]

Table 2.3 Comparison of Previous work

NO.	AUTHOR(S)	TITLE	FUNCTIONAL	REMARKS (method & application)
1	Ibrahim, Oladimeji. (2020)	Design and Construction of an Arduino-Based Solar Power Parameter-Measuring System with Data Logger	• Designed to connect a variety of sensors to an Arduino board, with the measured data being saved to a computer for further analysis.	• Voltage, current, light intensity, temperature, and pressure are among the five parameters to be measured.
2	M.venkaztaratnam, D.Yalamanda (2020)	Arduino based system to measure solar power	• Design the portable device casing that easy to move	• the method of identifying the device's accuracy • The Arduino-based solar power measurement system comprises panels set in a certain arrangement at a 45-degree angle to capture high-

				intensity solar radiation from the sun.
3	T. Kaur, J. Gambhir and S. Kumar (2016)	Arduino based solar powered battery charging system for rural SHS	• designing and developing a low-cost solar-powered battery charging system based on a microcontroller	• Built battery management system with LCD display and Wi-Fi module for storing and logging the data • Implement MPPT algorithms
4	Kusriyanto, M., Utama, H. S., & Effendi, I. (2021)	Prototype of automatic frequency control in micro hydro power plant with dummy load based on Arduino UNO and LabVIEW	• To make automatic frequency control dummy load with micro-hydro generator • To monitor the system using LabVIEW.	• Design micro-hydro power plant by using Matlab Simulink program • Component use: Arduino Uno, L298D motor drive, ZMPT101B AC voltage sensor, ACS712 current sensor, and PWM signal • set frequency range around 51-52 Hz

5	Petrollese, M., Seche, P., & Cocco, D. (2019)	Analysis and optimization of solar-pumped hydro storage systems integrated in water supply networks	• Optimising self-consumption of energy • To determine the feasible self-sufficiency rate and economic performance, various solar and turbine sizes are explored.	• Built a specific optimization method in the GAMS environment using the CPLEX solver.
6	Chitphairot, K., Nuchprayoon, S., & Mai, C. (n.d.) (2013)	Optimal generation scheduling of hydropower plant with pumped storage unit	• analyze the marginal operating expenses on an hourly basis	• optimum the generator based on hourly and annual generation costs • To fulfil the maintenance cycle, a minimum run time limit may be applied.
7	Rehman, S., Al-Hadhrami, L. M., & Alam, Md. M. (2015)	Pumped hydro energy storage system: A technological review	• to improve grid stability and encourage the use of additional intermittent renewable energy sources like wind and solar	• To improve plant performance and flexibility, advancements in turbine design are essential.

2.8 Summary

By implementing a solar-based battery charging technology, pumped storage hydropower will become more efficient and assist lower the costs of developing a hydropower plant. It can increase grid stability and stimulate the usage of more intermittent renewable energy sources by using solar as a renewable energy source. As a result, the design of a solar-powered battery charging system may be based on a calculation step for the number of batteries and the kind of solar panel, followed by the size of the solar panel.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In general, this chapter will cover the methodologies and procedures employed in this project, as well as the hardware components and software needed to accomplish it, with an emphasis on the efficacy of pumped hydropower storage combined with a solar charging system. This project will make use of an Arduino Uno microcontroller as well as software and suitable to ensure its success.

3.2 Methodology

In research, challenges such as specialized processes or approaches, analyzing information, and so on will certainly arise. The methodology is defined as a family of logic used to study reasoning or as a method of doing something. This is a small-scale prototype that will analyze the efficacy of pumped storage hydropower with a battery-based solar system by monitoring the reading of load current and load voltage.

3.3 Project architecture

A flow chart is a form of basic graphical representation of the entire project or programming. It shows the steps in a logical sequence. The flow chart depicts the project's progress from beginning to conclusion. The flow chart displays the progression of a project from start to finish. Pre-development includes the research and information collecting stages, as well as the comprehension of all programming languages and functional design. The initial stage of development, after the pre-development phase, is to include the data collection process into the Arduino coding. The last stage of the simulation results output into hardware and applications is performed during the post-development stage.

3.3.1 Project system

Figure 3.1 depicts the project's working system in order to better comprehend the project's system flow.

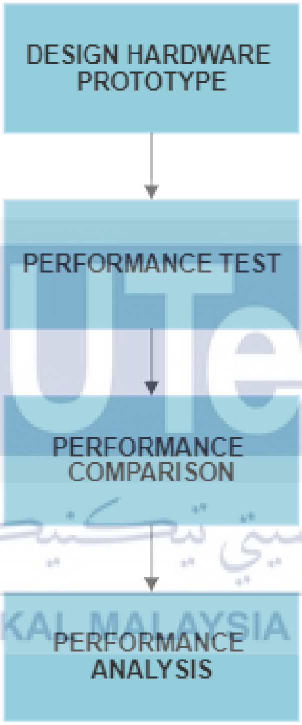

Figure 3.1 Process of project working system

a) Design hardware prototype

The project will be developed by using two water tanks (lower and elevated), water turbine generator, motor pump, solar panel, charge controller, battery, LCD, voltage sensor, current sensor, step down module and Arduino microcontroller.

b) Performance test

The project exposed under the sun and the output of water turbine generator is connected to low power electrical load such as lamp.

c) Performance comparison

The project will be compared to battery-based solar system and connected to the same load.

d) Performance analysis

The efficacy of the developed project will be analyzed in term of output power and consistency.

3.4 System architecture

The most important principle for carrying out this process is the current and voltage readings measured at each output load for the charge controller and 12V generator. In addition, the solar energy generated is used as the main source to power this system. The voltage stored in the charge controller will then be split between the battery and the load. Figure 3.2 will present this project block diagram.

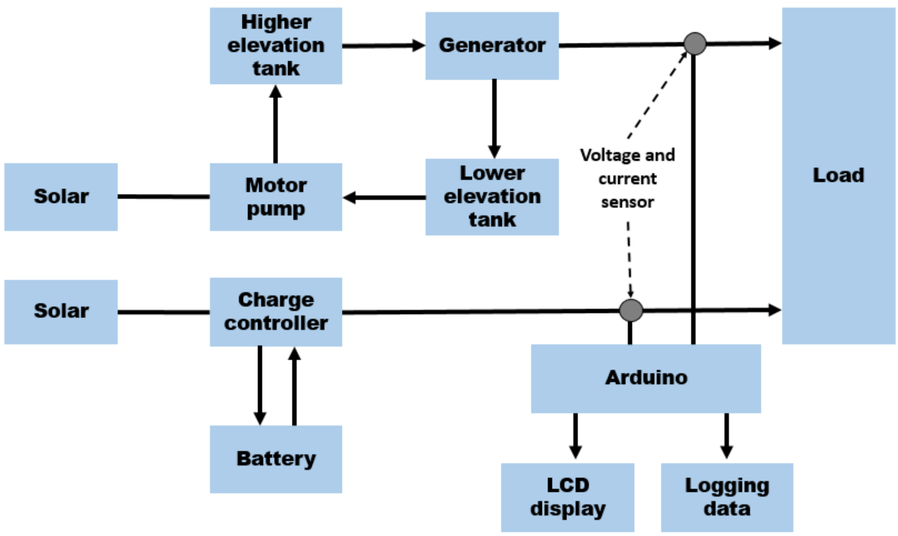

Figure 3.2 Project block diagram

a) Solar is main power supply for this system which is connected with motor pump and charge controller.
b) When motor pump turns ON, the water will be flow to the higher elevation tank then the water will flow through the generator and generate the electricity to the load.
c) At the same time, water will flow to lower elevation tank and turns back to the motor pump.
d) When charge controller turns ON, the energy will be store into battery and separate energy to the load.
e) The current and voltage can be read by using microcontroller Arduino UNO and it will display the measurement of current and voltage for each load.
f) The logging data will be store into SD card module.

3.5 Hardware components

Hardware is an important part of any project, especially a prototype model, because it can help us represent all of our real data and work. If a project just relies on software, such as simulation, it will be unable to obtain actual data/work, as the output of the simulator is dependent on computer/software calculations, which excludes other factors such as environmental factors. The best hardware allows us to study both hardware and software while also improving our skills such as designing and modelling.

3.5.1 Arduino Uno board

The Arduino Uno is a microcontroller board that is based on the Atmega328. This board is shown in Figure 3.3 that consists 14 digital I/O pins, a power connector, 6 analogue inputs pin, 16 MHz ceramic resonator, a USB connection, a RST button and an ICSP header. Furthermore, the microcontroller and other components on the Arduino board require 5V to operate. The Arduino UNO board is used to debug the coding programme and execute it in actual hardware to measure current and voltage for each load.

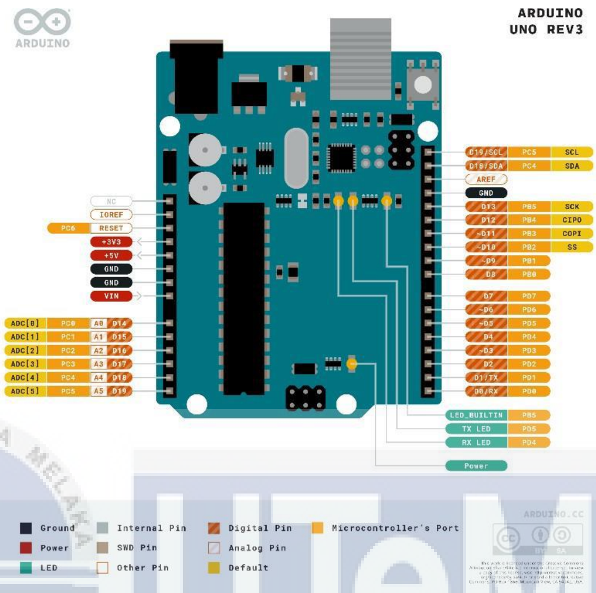

Figure 3.3 Arduino Uno pin configuration [18]

3.5.2 Water pump turbine micro-hydro DC flow

Water pump turbine micro-hydro DC flow is made of high-quality plastic that is both durable and long-lasting. The generator has a new high-quality all-metal waterproof technology that is resistant to corrosion and may be used in small water pumps. At same time, the product is an energy-efficient, environmentally friendly firm that can offer a wide range of products to utilize in many applications. The design of the Water pump turbine micro-hydro DC flow is shown in figure 3.4, and the specifications are presented in Table 3.1. This generator will be use to generate the voltage and current.

Figure 3.4 Water pump turbine micro-hydro DC flow

Table 3.1 Feature and specification of Water pump turbine micro-hydro DC flow

Features	Specification
weight	90g
voltage	12 V
Maximum Output voltage	80 V (1.2mpa)
Maximum Output current	220 mA
Line to line resistance	$10.5 \pm 0.5\Omega$
Maximum pressure of closed outlet	0.6mpa
Maximum pressure of open outlet	1.2mpa
Starting water pressure	0.05mpa
Life span of generators	$\geq$ 3000h

3.5.3 Submersible water pump

The submersible water pump is made with high-quality wear-resistant shaft and modern electrical components. Simple concept, good efficiency, good performance, and a long service life are all features of this product. Furthermore, it is possible to operate for an extended period of time without interruption, with low noise levels, safety, and environmental protection. This water pump will be use to pump water for lower elevation tank to higher elevation tank. As shown in figure 3.5, it will be placed in a lower elevation tank and the specifications are presented in Table 3.2

Figure 3.5 Water pump in lower elevation tank

Table 3.2 Feature and specification of submersible water pump

Features	Specification
Pump material	ABS
Size	5.5cm*3.5cm*4.5cm
Working temperature	0~75°C
Rated voltage	12 VDC
Maximum rated current	350 mA
Power consumption	4.2 W
Maximum flow rate	240 L/H
Power supply	Solar panel/DC electric source/battery

3.5.4 Current sensor module

For measuring the current flowing into the system, the ACS712 20A rating current sensor module illustrated in figure 3.6 was selected. While the output sensed voltage is separated from the measuring section, the sensing terminal of the current module may measure load current on medium voltage systems up to 230V AC mains. The sensor was operated with a 5V supply voltage in this application, and the analogue voltage output is proportionate to the current measured on the sensing terminals. The ADC on the microcontroller transforms the analogue value to a digital current equivalent that may be displayed or stored in the data logger.

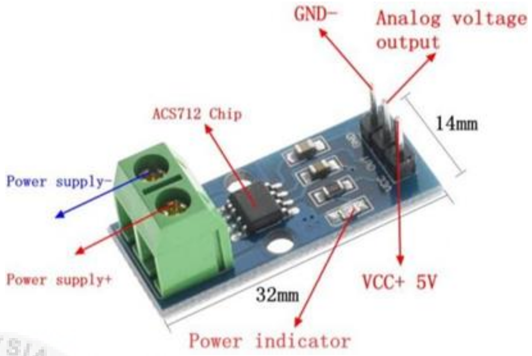

Figure 3.6 Current sensor module [19]

3.5.5 Voltage sensor module

The voltage sensor in figure 3.7 is used to measure the voltage of each load, which includes the load at solar-based battery charging and the generator. The analogue interface of the voltage module can detect input voltages up to 5V, however voltages more than 5V will not be recognized. A voltage divider was used to measure the solar-powered battery charging and generator voltage. The voltage sensor interface circuit is made up of two series resistors R1 and R2 with values of 30k and 7.5k, respectively, as well as a resistance factor (Rf).

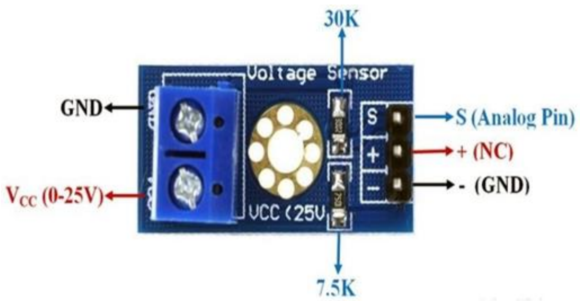

Figure 3.7 Voltage sensor module [20]

3.5.6 Liquid Crystal Display (LCD) I2C

A liquid-crystal display (LCD) I2C in figure 3.8 is a flat panel display, electronic visual display (EVD), or video display that makes use of liquid crystals' light modulating characteristics. The light that is emitted by liquid crystals is indirect. LCD 16X2 indicates that each of the two rows of a 16X2 LCD can display 16 characters, for a total of 32 characters at any given moment. In this project, the current and voltage outputs are shown on the two I2C LCD with different address which is 0X27 for display solar reading and 0X20 display generator reading shows in figure 3.9.

Figure 3.8 Liquid Crystal Display (LCD) I2C

Figure 3.9 LCD display for solar reading and generator reading

3.5.7 Tiny Real Time Clock(RTC) DS1307

This RTC module is built around the DS1307 clock chip, which supports the I2C protocol. It is powered by a Lithium cell battery (CR1225). The clock/calendar displays seconds, minutes, hours, days, dates, months, and years. For months with fewer than 31 days, the end of the month date is automatically adjusted, including leap year corrections. The clock has a 24-hour or 12-hour format and an AM/PM indicator. Real Time Clock (RTC) is used to track the current time and date for this project. Figure 3.10 depicts a tiny real-time clock powered by a lithium cell battery.

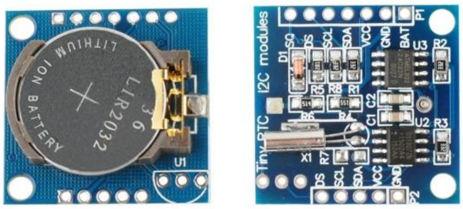

Figure 3.10 Tiny Real Time Clock (RTC) DS1307

3.5.8 Micro SD card

Figure 3.11 depicts the widely use of Micro SD cards in a variety of applications such as data logging, data visualization, and many others. Micro SD Card Adapter modules allow us to easily access these SD cards. The Micro SD Card Adapter module is a simple module with an SPI interface and an on-board 3.3V voltage regulator for powering the SD card. For this project, it is used to store the data such as date, time, voltage, and current.

Figure 3.11 Micro SD card

3.5.9 Charge controller

The charge controller in figure 3.12 is used in solar-powered battery charging systems. The charge controller has a lot of settings that are simple to operate like automated battery voltage selection for 6V or 12V. It also has a PWM charging method with an auto charge set point based on battery voltage. As an outcome, it has an LCD display will show voltages, currents, power, energy, and temperature. Display of solar charge controller shows that the value of voltage is 12.6V and indicator for solar and also battery connected with solar charge controller.

Figure 3.12 Solar charge controller

3.5.10 Solar panel

In this project, the water pump and battery-solar charging system are powered by solar panels, as shown in figure 3.13. One 50W solar panel is connected with a solar charge controller, and a 12V water pump is connected in series with three additional 10W solar panels.

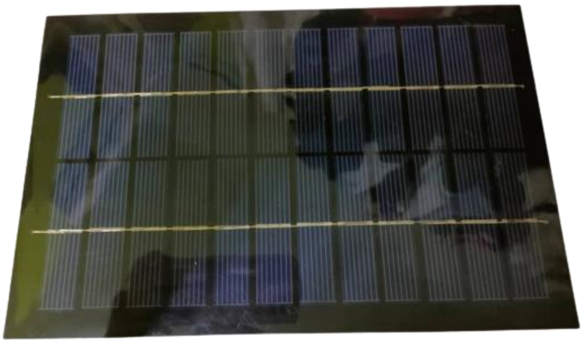

Figure 3.13 Solar panel

3.6 Software development

This is an essential software program that helps fulfill the entire project system. Without this application, the System cannot be designed connection circuit and test the functionality of the circuit on the built system.

3.6.1 Proteus 8

Figure 3.14 shows the proteus 8 is a set of software tools for simulating, designing, and sketching electrical circuits. This program is compatible with a wide range of microcontrollers used in various educational settings. As a result, it may assist even beginners in learning to build electronic circuits.

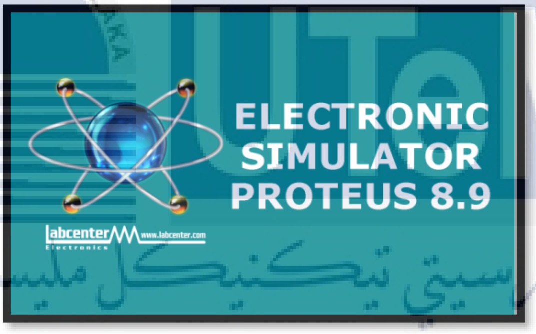

Figure 3.14 Proteus 8

3.6.2 Arduino IDE

The Arduino IDE is a software program that allows developers to write code in C and C++ using special code structure guidelines. The Wiring project is a software library that is included with the Arduino IDE and provides numerous common input and output processes. It also connects to Arduino and Genuino devices to upload applications and communicate with them. Furthermore, because proteus is a simulation basis program, Arduino may be simulated in it. Figure 3.15 show the illustration of Arduino IDE software.

Figure 3.15 Arduino IDE

3.6.3 Fritzing

Fritzing is a free design programme that can create schematics, design circuits on breadboards, and even create PCBs. Unlike many other circuit design suites, Fritzing is polished and heavily relies on vectorized images to create aesthetically pleasing circuits. The illustration of fritzing software is shown in Figure 3.16.

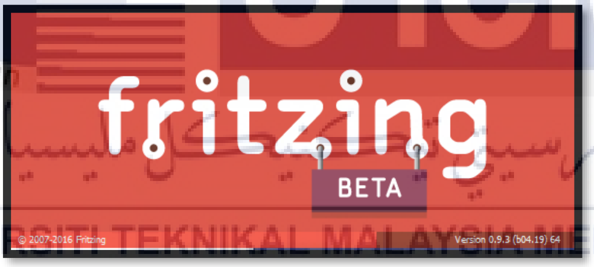

Figure 3.16 Fritzing

3.7 Electrical circuit design

3.7.1 Circuit design

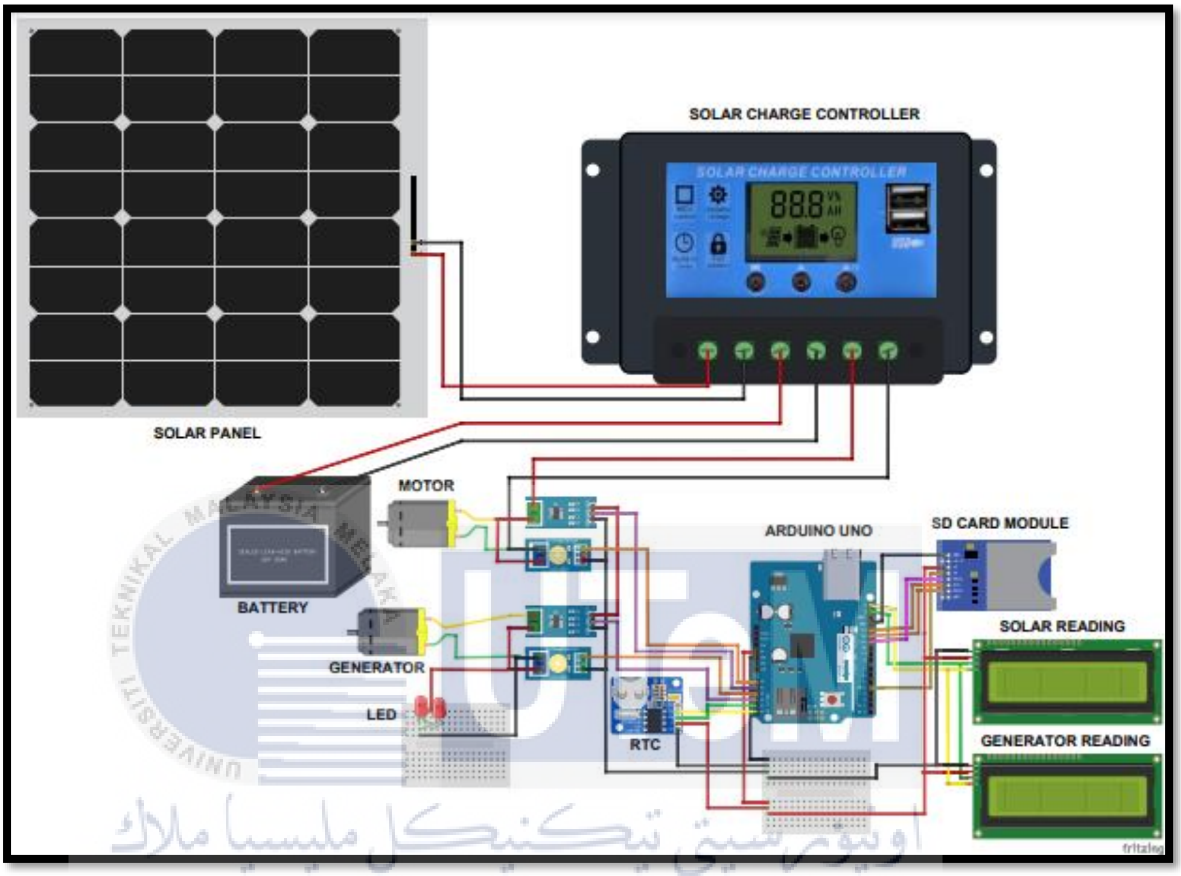

Figure 3.17 Electrical hardware circuit design in fritzing

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the findings and interpretation of data logging data for voltage and current readings. Voltage and current were measured for the charge controller output load and the generator output load. It is also displayed on the LCD to ensure that the data is stable with data logging.

4.2 Test result in software

4.2.1 Design in Proteus

This section demonstrates the system design in Proteus software so that the system's functionality can be tested as shows in Figure 4.1. In order to illustrate the range of water flow from the higher elevation tank to the lower elevation tank, the battery at the generator circuit is represented as a water pump. The variable resistor is then used to show the range of water flow. The range of voltage and current from sunlight is represented by the variable resistor at the solar panel component. Next, the SD1 is a SD card module that will restore the data logging. However, RTC1 ds1307 in Figure 4.2 show that the ds1307 clock monitor and desktop PC are synced. Last but not least, the virtual terminal in Figure 4.3 displays the voltage and current readings for the output of the entire system.

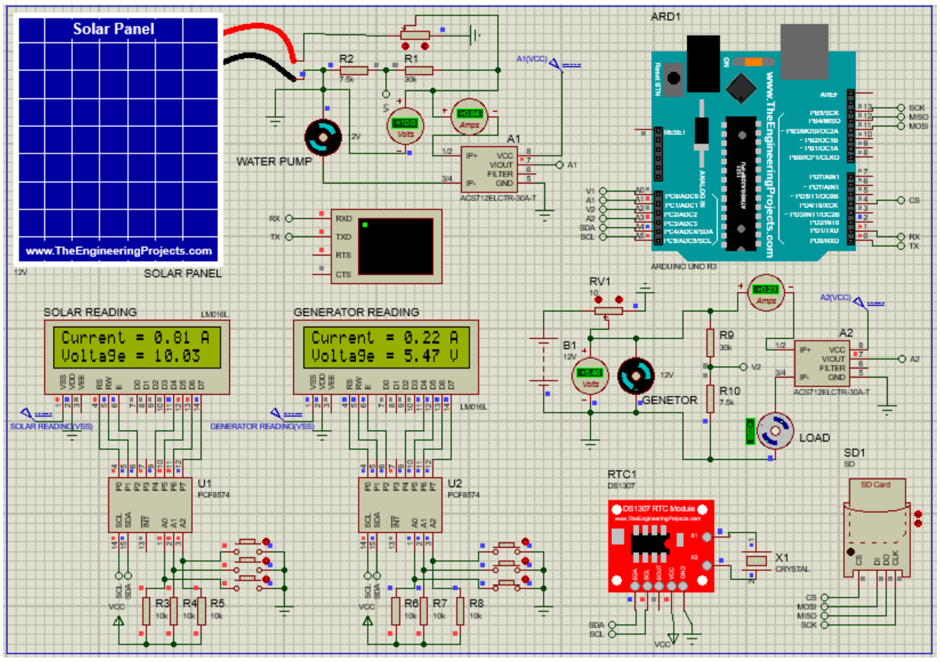

Figure 4.1 Design of solar system and generator

Figure 4.2 DS 1307 clock with PC desktop

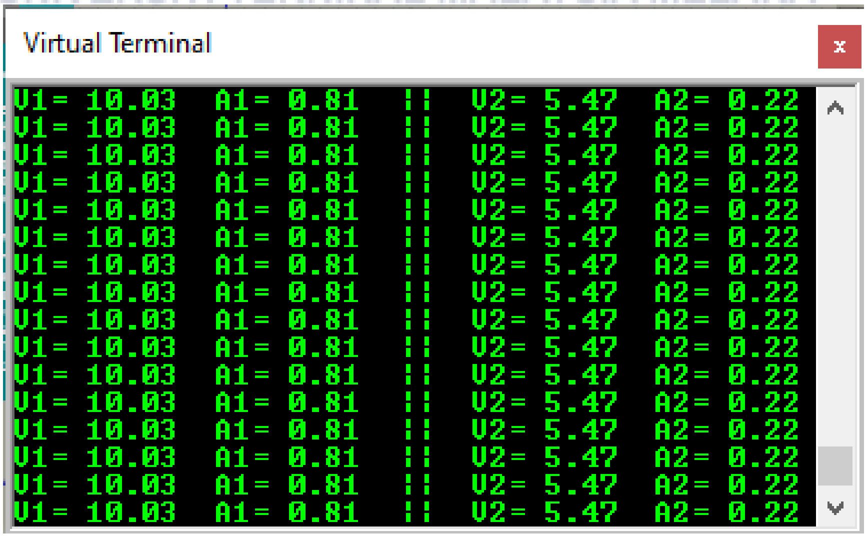

Figure 4.3 Virtual terminal for overall system output

4.3 Results and Analysis

4.3.1 System functionality

This project uses two different systems, with solar panels supplying as the main source of power. The first system is a battery-solar charging system in which the load on the solar charge controller is connected to the 12V motor as the output for this part. The second system is a hydroelectric generator, which requires two containers to represent the higher elevation tank and the lower elevation tank. Each water container is 26cm*17cm*16cm in size. Three 10W solar panels are connected in series and connected to the + and - terminals of the water pump to power the 12V water pump.

Water is pumped from the tank at the lower elevation to the tank at the higher elevation in order to start the hydroelectric generator turbine. Furthermore, time is taken according to the water level 1L,2L,3L,4L,5L, and 6L to see how long it takes for the water level to decrease by focusing on the speed. When water passes through the hydroelectric turbine generator, it rotates and reads voltage and current values. The load output used for this hydroelectric turbine generator is a buzzer.

Following that, the voltage and current values for both systems are measured using an Arduino Uno microcontroller, and the readings are then displayed on an LCD screen. The SD card module is used to store data logging, and the real time clock (RTC) ds1307 is used for real time purposes. The overall design prototype is shows in Figure 4.4.

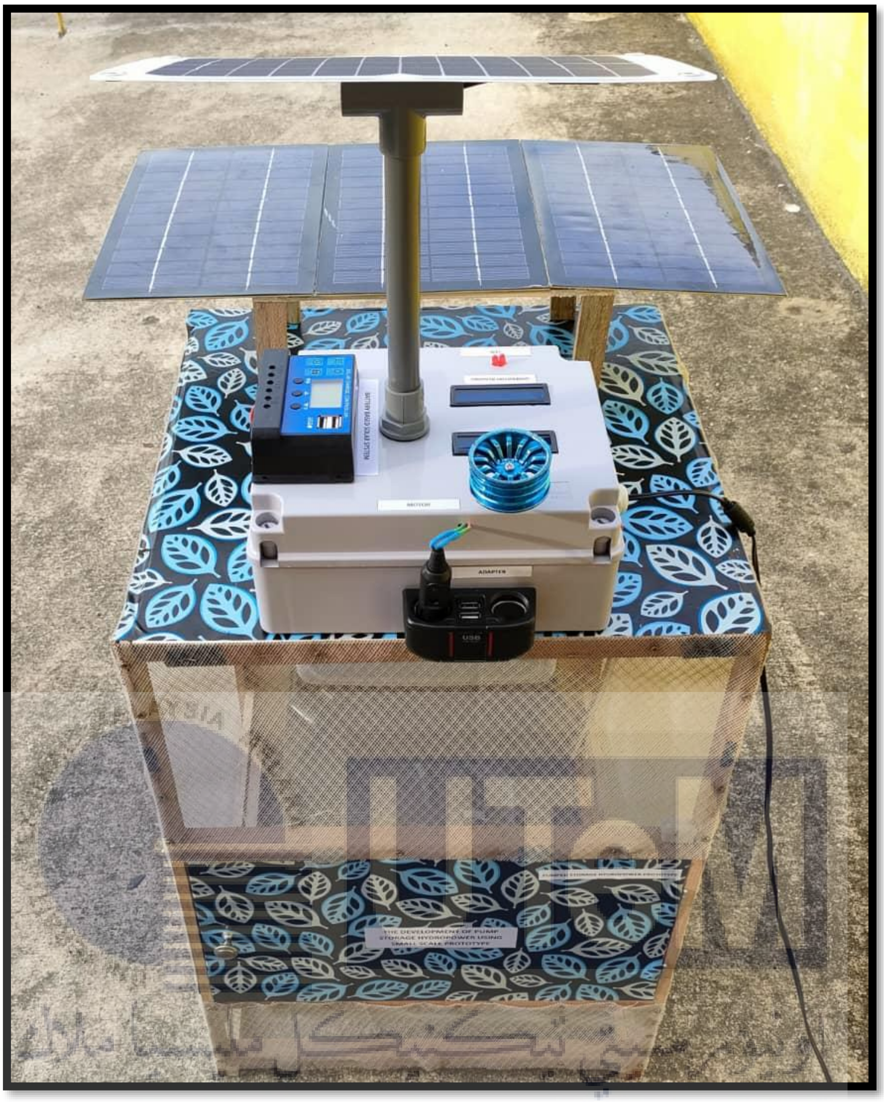

Figure 4.4 Overall hardware prototype

4.3.2 Hardware prototype view

This section shows that the actual view for the hardware prototype display from the top, left, front and back side views. The main component required in Figure 4.5 is the Arduino UNO microcontroller, which is connected to a power supply via an adapter cable. Following that, two sets of current and voltage sensors will be used to measure voltage and current readings on both project systems. Two LCD displays are used to display solar and generator readings. Finally, there is a battery for storing voltage from the solar charging controller, an RTC DS 1307 for real time, and an SD card module for data logging. Next, Figure 4.6 depicts a USB adapter connected to the load output of a battery-powered solar charging system. As shown in Figure 4.7, the front view includes two LCD displays, one motor, and two LEDs. Last but not least, figure 4.8 shows the back view of the solar charge controller.

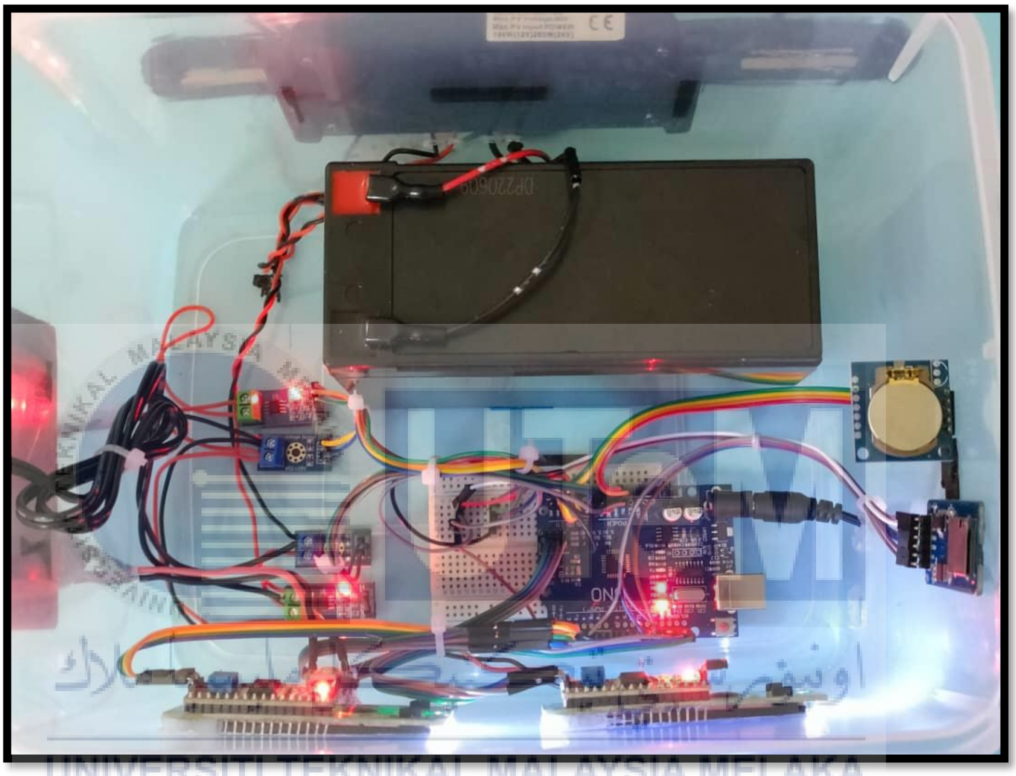

Figure 4.5 Top view

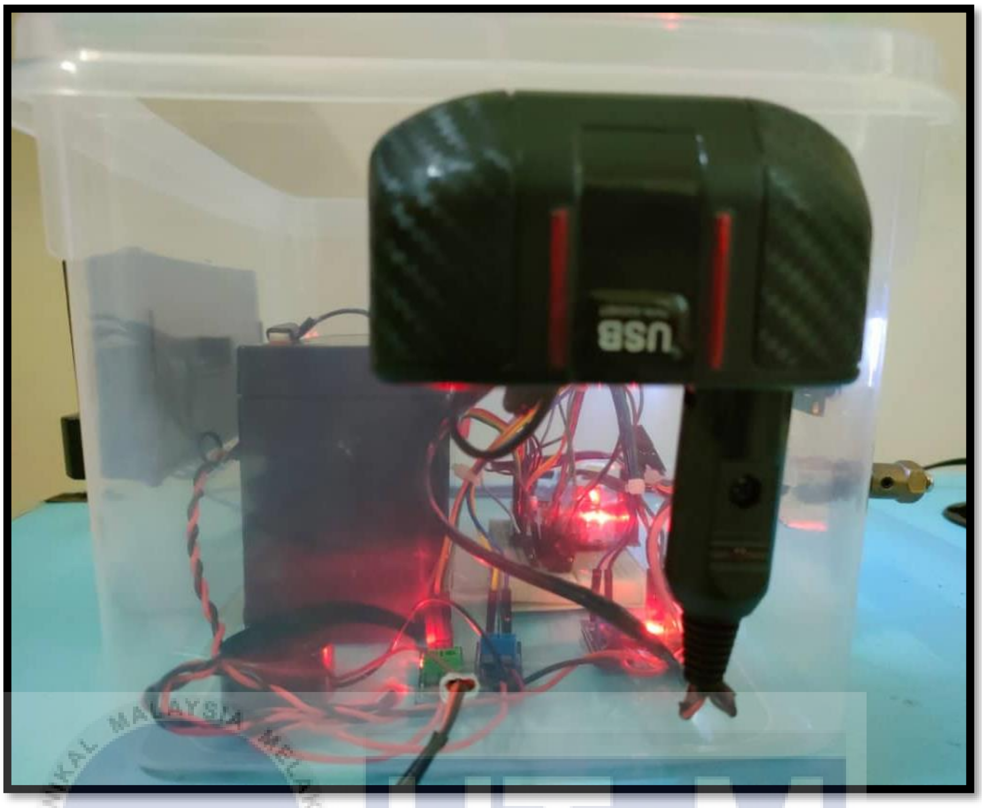

Figure 4.6 Left side view

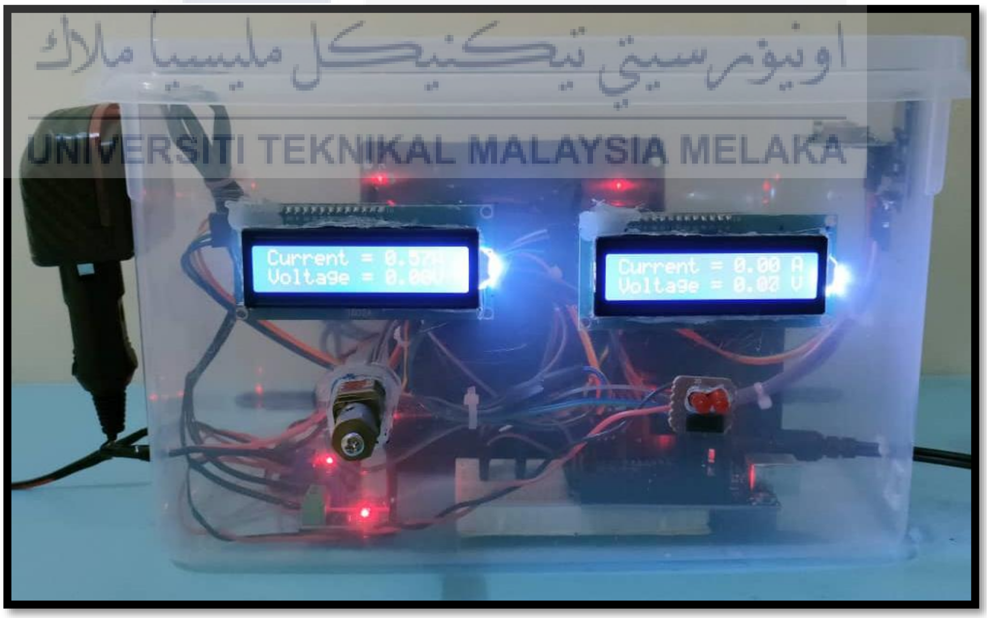

Figure 4.7 Front view

Figure 4.8 Back view

4.4 Battery-based solar charging system analysis

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

Table 4.1 Reading voltage and current for sample 1

TIME (HOURS)	VOLTAGE (V)	CURRENT (A)
9:00 AM	12.0	0.57
10:00 AM	12.02	0.38
11:00 AM	12.05	0.47
12:00 PM	12.02	0.28
1:00 PM	11.92	0.52
2:00 PM	11.88	0.42
3:00 PM	11.85	0.32
4:00 PM	11.56	0.12
5:00 PM	11.75	0.23

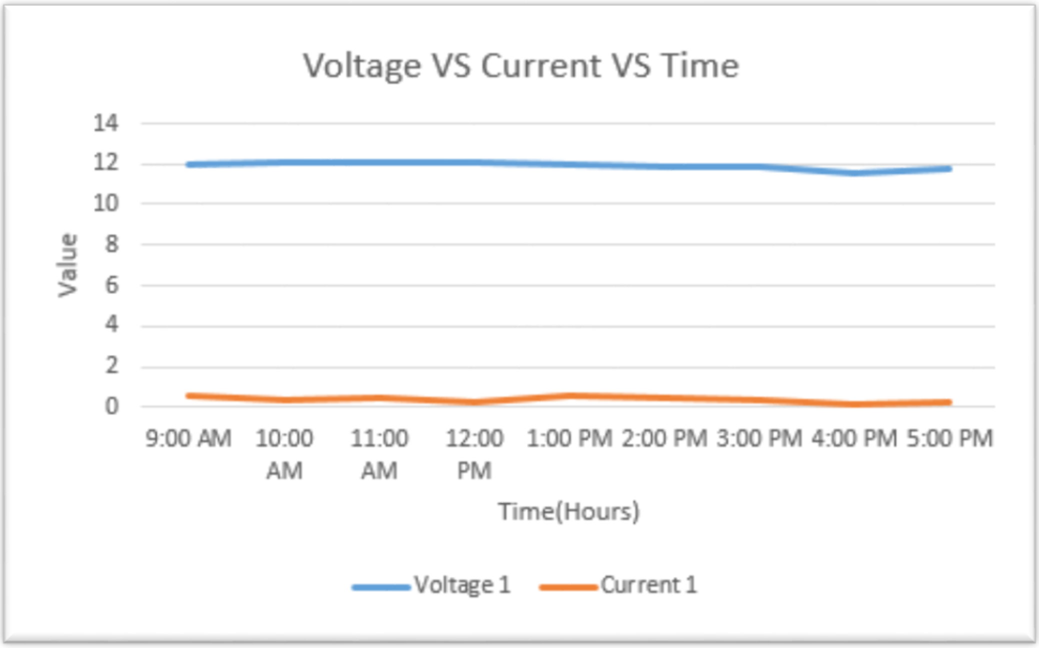

Figure 4.9 Graph of reading voltage and current for sample 1

Based on Table 4.1, it shows that the voltage reading decreased slightly starting at 1 pm this is due to the appearance of clouds and drizzle around 4 pm. Figure 4.9 shows that the reading of current at value 0.52A are reach at maximum power because solar panel is expose to the sunlight for too long so the current value decrease due to increasing solar panel temperature.

Table 4.2 Reading voltage and current for sample 2

TIME (HOURS)	VOLTAGE (V)	CURRENT (A)
9:00 AM	11.95	0.23
10:00 AM	11.88	0.18
11:00 AM	8.94	0.03
12:00 PM	12.17	0.57
1:00 PM	12.1	0.18
2:00 PM	11.88	0.37
3:00 PM	11.85	0.23
4:00 PM	12.07	0.67
5:00 PM	11.92	0.18

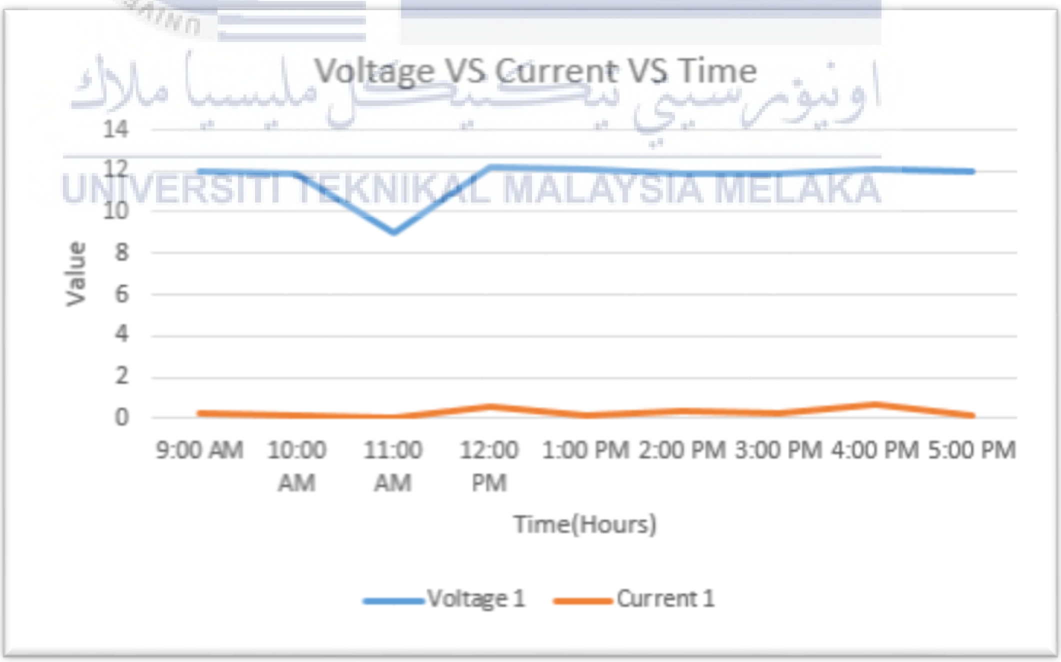

Figure 4.10 Graph of reading voltage and current for sample 2

Based on Table 4.2, it shows that the value of voltage slightly decreases from 11.88V to 8.94V because of cloudy weather at 11am. At 12pm, the voltage slightly increases up to 12.17V due to bright and sunny weather. Due to erratic weather, there is a slight voltage change at 2 until 4pm. There are two times the number of current increases until it reaches the maximum power level which is 0.57A at 12 noon and 0.67A at 4 pm. so Figure 4.10 shows that there is a change in the weather that day.

Table 4.3 Reading voltage and current for sample 3

TIME (HOURS)	VOLTAGE (V)	CURRENT (A)
9:00 AM	11.9	0.03
10:00 AM	11.92	0.08
11:00 AM	11.95	0.28
12:00 PM	12.12	0.43
1:00 PM	12.02	0.72
2:00 PM	11.92	0.42
3:00 PM	11.83	0.13
4:00 PM	11.78	0.23
5:00 PM	11.75	0.18

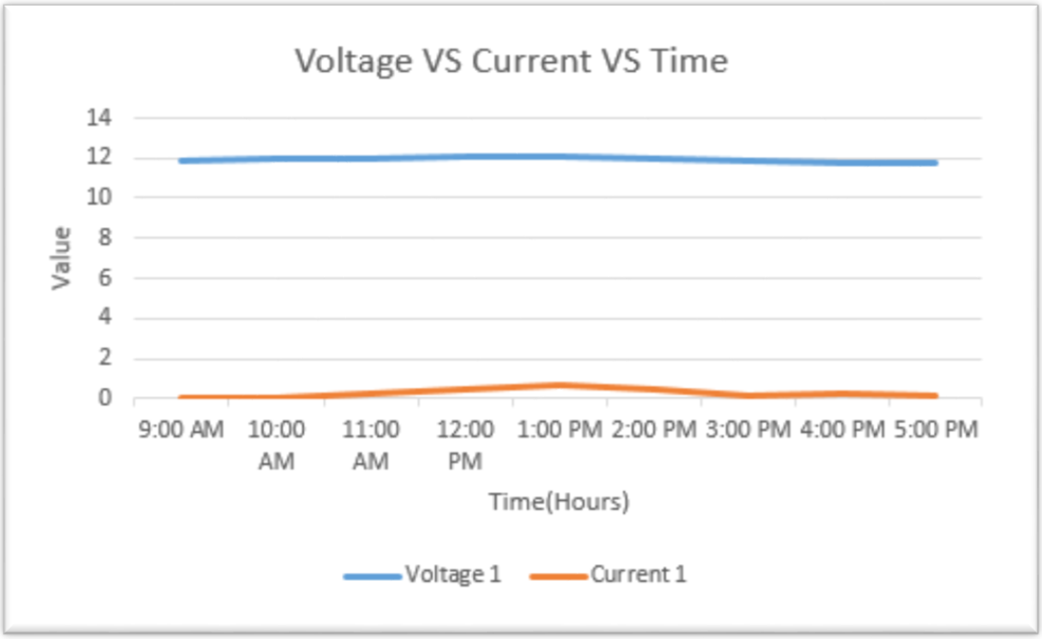

Figure 4.11 Graph of reading voltage and current for sample 3

According to data based on Table 4.3, the voltage value at 9am is 11.9V and at 12pm it is 12.12V, indicating that the peak sun hour has passed then the voltage value at 5pm is 11.75pm. Then, the value of current at 1pm is 0.72 is reach at maximum power so that the value will be decrease due to increasing solar panel temperature. The value of voltage and current are precise to form a bell shape curve on a sunny day by referring the Figure 4.11.

4.5 Pumped storage hydropower prototype

Table 4.4 Data of hydroelectric generator for sample 1

VOLUME (ℓ)	VOLTAGE (V)	CURRENT (A)	TIME (S)
1	0.7	0.05	10
2	1.2	0.1	22
3	1.3	0.22	70
4	1.54	0.37	92
5	1.66	0.58	100
6	1.78	0.66	180

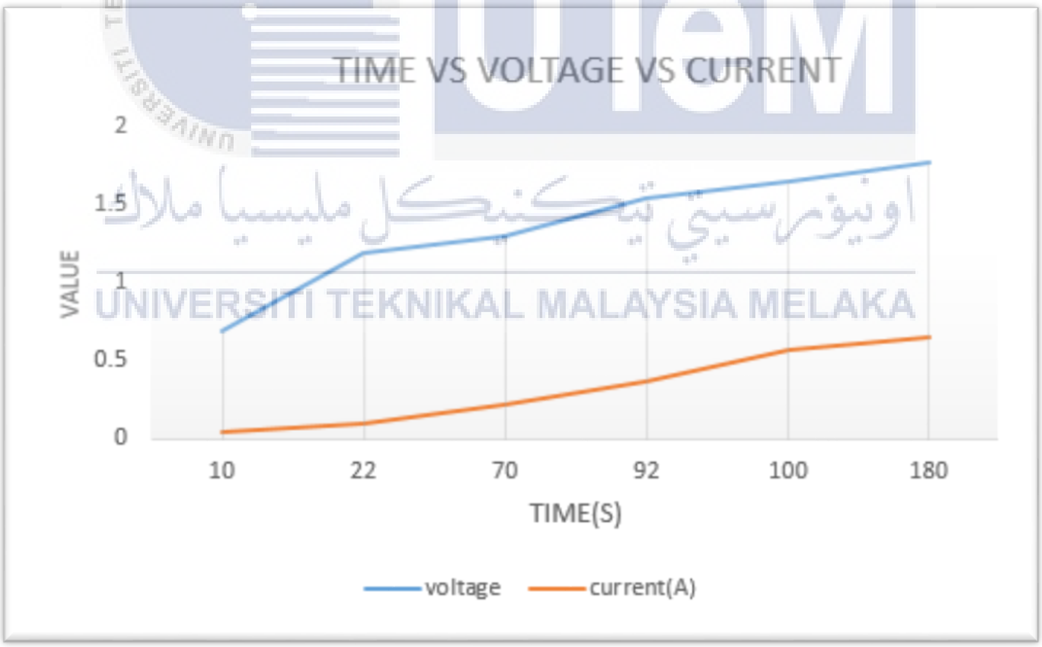

Figure 4.12 Graph of data sample 1

According to Table 4.4, it takes 10 seconds for the higher elevation tank to reach 1 liter of water volume. Furthermore, it takes 180 seconds for the water pump to pump water to the higher elevation tank to reach 6 liters of water volume. On graph 4.12, the voltage reading increases from 0.7V to 1.78V, and the current reading increases from 0.05A to 0.66A. This is because the generator's rotation produces voltage and current based on the increase in the water volume level in stages.

Table 4.5 Data of hydroelectric generator at sample 2

VOLUME (ℓ)	**VOLTAGE (V)**	**CURRENT (A)**	**TIME (S)**
1	0.66	0.03	10
2	1.22	0.27	36
3	1.44	0.32	64
4	1.51	0.39	96
5	1.54	0.42	130
6	1.61	0.46	177

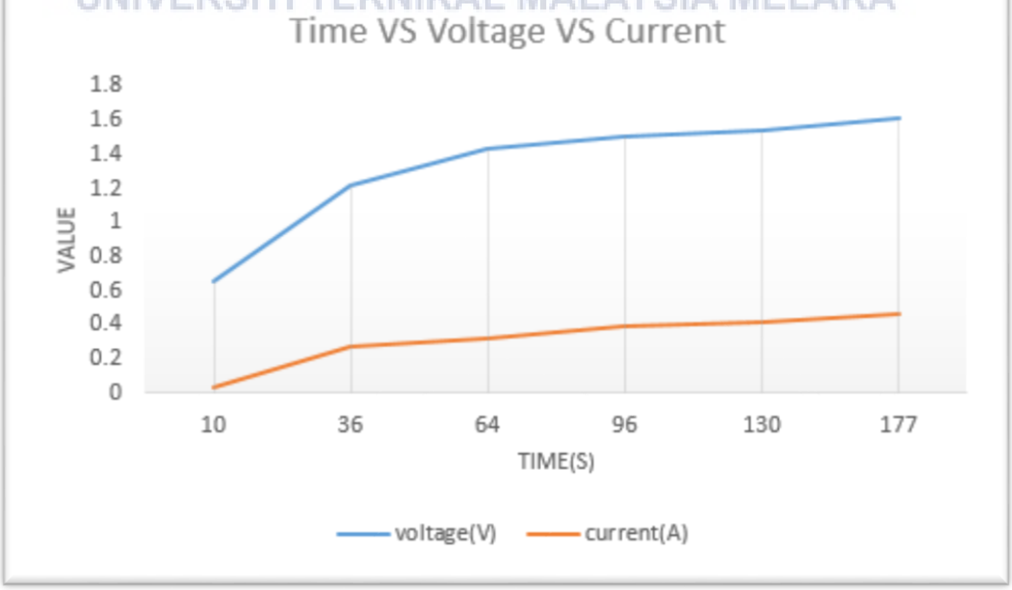

Figure 4.13 Graph of data sample 2

According to Table 4.5, the higher elevation tank takes 10 seconds to reach 1 litre of water volume, and the voltage reading is 0.66V with a current of 0.03A. Furthermore, it takes 177 seconds for the water pump to pump water to the higher elevation tank in order to reach 6 litres of water volume, with the voltage reading being 1.61V and the current reading being 0.46A. Besides that, the time required for the water pump to pump for sample 2 is slightly faster than for sample 1. As a result, Figure 4.13 depicts the increase in voltage and current caused by the generator's rotation.

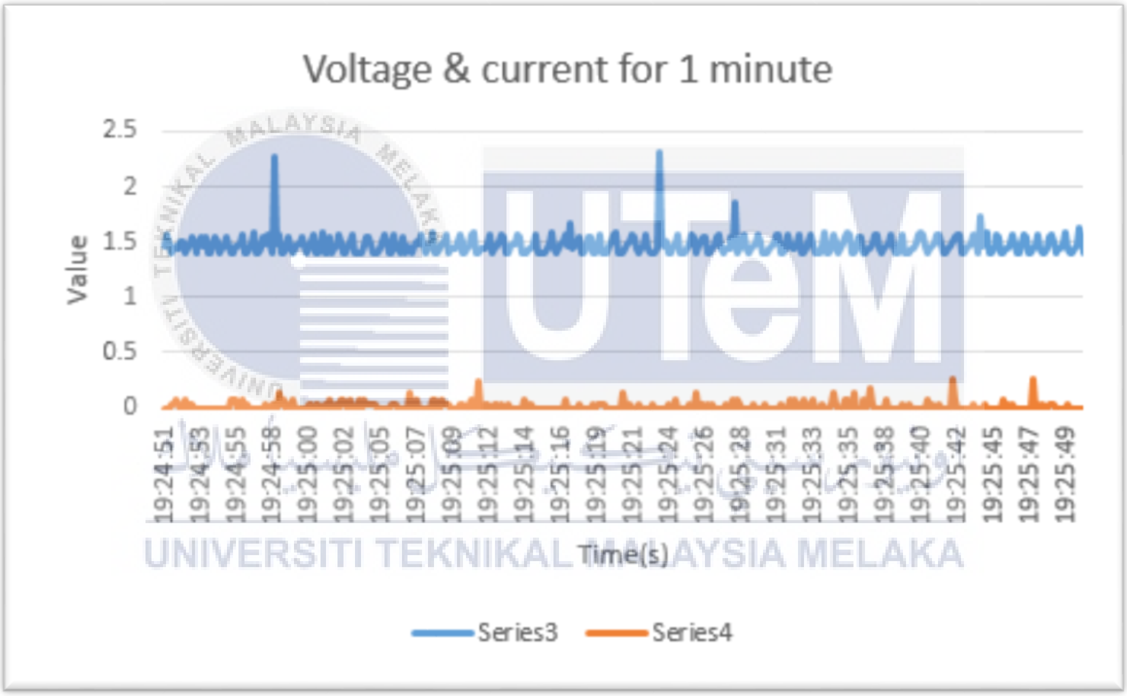

Figure 4.14 Graph for 1 minute

The voltage and current readings for one minute are shown in Figure 4.14. Series 3 represents voltage, while series 4 represents current. The sinusoidal wave illustrates how the amplitude of a variable changes over time.

4.6 Summary

In a nutshell, this system can be implemented using basic software, but many things must be changed depending on the suitability of the actual system that has been planned. However, it has been demonstrated that the main parameters can be tested at this early stage. This system has made it simple and efficient to monitor battery-based solar charging systems and pump storage hydropower generators. Some of the weaknesses discovered during the preliminary testing must be resolved by using better system settings.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Overall, this project has achieved all three objectives using the method defined in Chapter 3. Voltage and current readings on both systems can be recorded, saved to an SD card, and displayed on both LCDs.

Furthermore, there was an issue with the hydroelectric generator in the beginning where the turbine did not work properly, resulting in no either current or voltage being produced. Following that, the generator reading for low voltage and current is produced as a result of the voltage drop. In the hydropower storage pump section, the load output, i.e. buzzer, is changed to two LEDs for indicator. The weather has an impact on the main source of solar energy because the voltage produced is dependent on sunlight.

Finally, battery-based solar is better compared to pump storage hydropower because voltage and current results show that hydropower generation is less than battery-based solar. In other words, solar powered by batteries generates more voltage and current.

5.2 Project objectives

5.2.1 To develop an Arduino-based circuit that measures load current and voltage

The first goal was to develop an Arduino-based circuit that measures load current and voltage, which was accomplished by using an Arduino UNO as a microcontroller, an ACS712 current sensor to measure current, a voltage sensor to measure voltage to both systems, a data logger, and an RTC DS 1307 to store data in real time.

5.2.2 To design a small scale prototype pumped storage hydropower using solar-powered system

A small scale prototype for pump storage hydropower with a container size of 26cm*17cm*16cm and a height of lower container to high container is 47 meters has been successfully designed. The solar energy source is used to activate the water pump, which pumps water from the lower container to the upper container. The water from the upper container will flow through the hydroelectric generator turbine, generating voltage and current as a result of the rotation. As a result, the data has been recorded in Chapter 4.

5.2.3 To compare the efficacy of pumped storage hydropower prototype with battery-based solar system.

According to the data, the efficacy of the battery-based solar charging system is better than that of the pump storage hydropower system because the output produced by the generator is lower in the battery-based solar system. However, the pump storage hydropower may much more efficient is a bigger elevated tank is used.

5.3 Project limitations

During the development process, there were several limitations and challenges to completing this project. One of the main factors limiting this process and causing the data collection process to take a long time is the turbine generator not working properly. Next, solar energy is required for this project to turn on the water pump and charge the battery. Because Malaysia is currently having the rainy season, it is difficult to obtain voltage and current readings. As a result, the turbine generator stops rotating and produces a low output value. Finally, because the cost of some components is high, this project has a relatively high cost.

5.4 Future improvement

In future improvement, this project can be applied by using the Internet of Things (IoT) for monitoring system. By implementing IoT in this projects, the pumped storage hydropower can be monitored by using application in electronic device. This project can also be made safer by adding a buzzer and a light-emitting diode (LED) for the hardware prototype, as well as sending notifications to a smartphone as an alarm when the system is in danger, such as when a solar panel is exposed to the sun for an extended period of time, causing the panel to heat up and lose some of its efficiency. Additionally, increasing the water tank container's size, volume of water as well as increase height of higher elevation tank makes it much simpler to achieve higher voltage and current.

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APPENDICES

Appendix A Gantt chart for PSM 1

NO.	Project Activity	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	BDP 1 Briefing by JK PSM, FTKEE														
2	Discussion with Supervisor														
3	Research academic papers														
4	Study background project														
5	Prepare chapter 1: Introduction														
6	Study raw materials														
7	Update to supervisor work progress 1														
8	Prepare chapter 2: Literature review														
9	Prepare chapter 3: Methodology														
10	Report draft submission														
11	Update to supervisor work progress 2														
12	Prepare report and slide presentation														
13	Submit report to supervisor and panel														
14	PSM presentation evaluation														

Appendix B Gantt chart for PSM 2

NO.	Project Activity	Week															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	BDP 2 Briefing by JK PSM, FTKEE																
2	List out and compare price of components																
3	Buy and receive components																
4	Redesign and confirm the dimension of hardware design																
5	Make connection (wiring) between components and microcontroller																
6	Write program code and testing																
7	Prepare final draft thesis and																
8	Prepare and submit draft report and poster																
9	Submit final report to supervisor and panel																
10	PSM presentation																