Faculty of Electrical Technology And Engineering

MONITORING PORTABLE SOLAR GENERATOR DEVELOPMENT FOR EMERGENCY AND REMOTE USAGE

Nazmi Aqil Bin Mohd Baki

Bachelor of Electrical Engineering Technology with Honours

2023

MONITORING PORTABLE SOLAR GENERATOR DEVELOPMENT FOR EMERGENCY AND REMOTE USAGE

Nazmi Aqil Bin Mohd Baki

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 DAN KEJUTERAAN ELEKTRIK

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : Monitoring Portable solar generator for emergency and remote usage

Sesi Pengajian :Tahun 4 semester 1

Saya Nazmi Aqil Bin Mohd Baki 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:

(TANDATANGAN PENULIS)

Alamat Tetap:
348, Persiaran Desa Ampang 6,
Taman Sri Ampang,Ampang,Selangor

(COP DAN TANDATANGAN PENYELIA)

DATIN DR. FADZILAH BINTI SALIM
PENSYARAH KANAN
Fakulti Teknologi dan Kejuruteraan Elektrik
Universiti Teknikal Malaysia Melaka

Tarikh: 14/2/2024

Tarikh: 14/2/2024

*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 "monitoring portable solar generator development for emergency and remote usage" 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 : Nazmi Aqil Bin Mohd Baki

Date : 14/2/2024

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 : Datin Dr. Fadzillah Binti Salim

Date : 14/2/2024

Signature :

Co-Supervisor Name : Amalia Aida Binti Abdul Halim

Date : 14/2/2024

DEDICATION

To my beloved mother, Norliza, and father, Mohd Baki,
And my supervisor and also my academic advisor at university teknikal Malaysia Melaka ,Datin Dr Fadzillah Binti Salim helping me a lot to throughout this project .thankyou for an opportunity
That has been given to me to study this project and help me to do a research about this project. Not forget either to my co-supervisor, madam Amalia Aida that also help throughout the project 1 and 2

ABSTRACT

This study focuses on harnessing clean energy through the development of portable solar generators, with an emphasis on efficient technology. Solar panels, utilizing polycrystalline technology, are employed to convert sunlight into direct current (DC) electricity. To store this energy, sealed lead acid batteries are utilized, managed by a solar charge controller to prevent overcharging. Recognizing the need for alternating current (AC) energy in practical applications, an inverter is integrated into the system. The project's effectiveness is ensured through careful circuit design, drawing insights from previous related studies. Monitoring and evaluating the generator's performance involve measuring voltage and current using a multimeter, while irradiance and temperature are gauged by a BH1750 sensor and a DHT11 sensor, respectively. The experiment spanned six days to comprehensively assess the generator's capabilities. Results indicate that the power output aligns with sunlight intensity, with higher solar exposure yielding increased energy production. However, it is noted that excessive temperatures can impact solar panel efficiency. The goal of this initiative extends beyond technological innovation; it aims to provide practical solutions for individuals in areas without grid electricity, benefiting farmers, campers, and travelers. By embracing renewable energy sources like solar power, this project contributes to the reduction of air pollution and fosters sustainable energy practices.

ABSTRAK

Kajian ini menekankan potensi penggunaan sumber tenaga yang bersih tanpa menimbulkan pencemaran serius. Tenaga suria, yang bergantung kepada cahaya matahari, dapat dihasilkan melalui penggunaan solar panel. Walau bagaimanapun, untuk mengelakkan pembaziran tenaga, diperlukan tempat penyimpanan seperti bateri asid plumbum. Projek ini mengutamakan penggunaan solar sebagai sumber utama tenaga dan bateri sebagai penyimpanan. Analisis dilakukan terhadap projek-projek sedia ada dari kajian terdahulu, dan reka bentuk litar sangat penting untuk memastikan keberkesanan projek ini. Penggunaan panel solar policrystalline dan bateri asid plumbum tertutup diimbangi dengan pengawal cas solar untuk mengelakkan penuhan bateri. Dalam mengukur prestasi penjana solar mudah alih, voltan dan arus diukur menggunakan multimeter. Sinaran cahaya matahari dan suhu juga diukur dengan menggunakan sensor BH1750 dan DHT11 untuk memastikan penghasilan tenaga maksimum dalam pelbagai keadaan cahaya dan waktu. Kajian dilakukan selama enam hari untuk menilai prestasi penjana. Hasil kajian menunjukkan bahawa penghasilan kuasa meningkat sejajar dengan intensiti cahaya matahari. Namun, suhu tinggi boleh memberi impak kepada kecekapan panel suria. Penggunaan tenaga boleh diperbaharui seperti solar dapat membantu mengurangkan pencemaran udara. Diharapkan, penjana suria mudah alih ini memberi manfaat kepada petani, perkhemahan, dan pengembara ketika elektrik grid tidak tersedia.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to my supervisor, *Datin Dr Fadzillah Binti Salim* and co-supervisor, Amalia Aida Binti Abdul Halim for their precious guidance, words of wisdom and patient throughout this project.

I am also indebted to Universiti Teknikal Malaysia Melaka (UTeM) for the financial support through, which enables me to accomplish the project. Not forgetting my fellow colleague, Arif Irfan and Feirdous for the willingness of sharing his thoughts and ideas regarding the project.

Finally, I would like to thank all the staffs, fellow colleagues and classmates, the Faculty members, as well as other individuals who are not listed here for being co-operative and helpful.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

δ	-	Voltage angle
%	-	Percentage
	-	
	-	
	-	
	-	
	-	
	-	

LIST OF ABBREVIATIONS

V	-	Voltage
AC	-	Alternating current
DC	-	Direct Current
PWM	-	Pulse Width Modulation
MPPT	-	Maximum Power Point Tracking
RV	-	Recreational Vechile
UL	-	Underwriters Laboratories
ETL	-	Electrical Testing laboratory
CSA	-	Canadian Standard Association
RMS	-	Root Mean Square
BDP1	-	Bachelor Degree Project 1
BDP2	-	Bachelor Degree Project 2
W	-	Wattage
I	-	Current
Mcb	-	Miniature circuit breaker
Rccb	-	Residual circuit breaker
P	-	Power

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Humans always search for the most readily available and ecologically friendly sort of power as they develop since there is a dearth of it. Renewable energy is a power produced from sustainable natural resources such solar, wind, water, tides, hydropower, biomass, and geothermal energy. solar is one of the renewable energy that is effectively used in Malaysia because Malaysia receives a lot of sunny days throughout the year. the use of solar has also been widespread in Malaysia and continues to be viable. Malaysia has the highest solar radiation that can be used to generate electricity.

The primary source of power has shifted from fossil fuels to renewable energy sources, such electricity. Fossils are predicted to end within the next hundred years. Solar energy is one of the renewable energy that is very effective and widely used throughout the country. This is because it is an inexhaustible source and is environmentally friendly. This is the opposite of fossil sources. Mostly fossil source were used as the main source of energy in countries with hot climates around the world.

Solar systems are often used for buildings, industries and homes. However, installation for large building indoors and home that require a large installation. As for farmers, campers and travellers who need a little electricity, it is appropriate to use a portable solar generator. This is because it is easy to carry everywhere and can be charged anywhere when there is a sunlight.

1.2 Addressing Global Warming Through Weather Sensing Project.

One global issue related to solar is solar energy depends on weather and solar can charge the battery only in peak sun hour between 12 hours. Solar panel also can’t have a shading because this will make solar produce less energy. So that, when make a solar installation, installer have to install at a good place without shading unless because of cloud and shading. Solar energy systems either use photovoltaic (PV) panels or mirrors to focus solar radiation to convert sunlight into electrical energy.

Solar power can be converted into electricity, thermal energy storage, or batteries. However, the use of solar in Malaysia is not too much because of the high installation cost. In addition, the use of solar requires sunlight to produce electricity. This is quite complicatedto obtain permanent sunlight. Therefore, a battery is installed to store the energy that has been charged by the solar panel. The use of solar is very widespread nowadays to save on the use of bills electricity to consumers. Not many people use solar in Malaysia because they can’t afford to install and are not exposed to the benefits of solar

1.3 Problem Statement

Not all places have electricity supply, especially in the forest or other remote areas. People who work at the place where there is no source of electricity, have to use their own energy and strength to do their work. These people to get a source of electricity may requirea certain procedure to apply. And it will takes some time to set it.

Although, there are generators to produce electricity that they can use, the existing generators require fuel to use it. Using fuel may cause air pollution. This will also cost the user some amount of money for fuel. This will also harm the user because they need to spend money for fuel. However, fossil fuel is expected to decrease within a few years.

Moreover generators are quite heavy because current generator use an engine system and requiremany components for installation. In addition, they are like motor engines and almost all shapes are made of iron. This cause very much difficulty and inconvenience to carry the generator everywhere.

This is very contrary to the solar system which is proven to produce clean energy without air pollution, inexpensive, easy to get and portable

1.4 Project Objective

In order to help people to get electrical energy anywhere they have been although in the forest. This led to the three main goals of the project:

a) To analyse the existing solar generator from an article

b) To develop a portable solar generator from calculation and hardware choosen

c) To test and evaluate the model perfomance of voltage, current and power of a portable solar generator for emergency and remote usage and monitoring the irradiance of sunlight and surrounding temperature

1.5 Scope of Project

The goal of this project is to make it easier for people to use electricity sources. This project uses solar photovoltaic 12v to produce electrical energy then to charge a battery.

a) A 12v battery is used for storing the energy produced by solar. Charger controller isused to monitor the storage percent of the battery

b) From charger controller also can use a load but only for DC load

c) From charger controller an Arduino were connected to Arduino uno because want to use sensor to monitor temperature and irradiance

d) From charger controller also can use a load but only for DC load

e) DC circuit breaker also used to protect component

f) An inverter to convert DC to AC are used because of many component are using AC supply

g) Ac breaker also were use to protect ac equipment

h) To connect all the components, the wire use from solar to inverter is 2.5 mm^2.andfrom inverter to load is 2.5 mm^2.for socket also 2.5 mm^2 and for lamp is 1.5 mm^2

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In today's modern society, electrical energy quite important for people to use their electrical mechanism. This implementation can be change is by green energy to reduce fromwasting electrical energy. Some green energy also has an impact to our environment. Windhas less impact to ecology.in this chapter, this research is about how to implement solar system as our energy resources. Solar is better renewable energy compared to wind and hydro if it can be designed and managed carefully. Hydropower is the most that will give a large impact to ecology [1]. Green energy can protect our environment. In Malaysia there aremany organizations organize green campaigns such as Environmental Protection Society ofMalaysia (EPSM), Malaysian Environmental NGO (MENGO) and Rawat Every Environment Special Sdn. Bhd. (TRESS) [2].

2.2 Understanding Current Issue in the Literature

Through a review of the literature study, according to the data as many as 72.7% still use non-renewable energy such as oil, coal, nuclear energy and as many as 27.3% that use renewable energy sources [3]. This is worrying for the environmental conditions that will be affected by the pollution produced by non-renewable energy sources. When fossil fuels are used, this will leave a certain amount waste in the form of solid and gaseous materials. This waste, caused by fossil fuels, cannot be reused in any way and therefore, it causes the environment pollution [4]. It is important to share the usage of solar. However solar system has a high cost to build [5]

To start decreasing the usage of non-renewable energy that can cause air pollution is by using portable solar generator. Air pollution can be decreased by using a portable solar. The price of a portable solar is affordable. A portable solar generator can solve that problem as it would replace the environmentally unfriendly petrol and diesel generator being used by many people. A portable solar generator also can be used in rural areas because power supply cannot be channeled to a certain place but with a portable solar generator it will be easier toget electricity supply [6]. Malaysia is close to the equator. This has led Malaysia receiving a significant quantity of solar radiation throughout the year, according to the Malaysian average monthly study estimate [7].

2.2.1 Building of a portable solar AC & DC power supply

The development of this project is to find new energy because traditional methods with use natural sources sooner or later it will run out and at the same time will produce air pollution. This project was using polycrystalline 5V 5W solar panel to absorb power from the sun. The charger controller has been designed to prevent overcharging of battery.12 volt sealed lead acid battery are used in the system to stored energy produce from solar panel. Square wave inverter was used in this project due to the cost, but the system can be operated as usual. Voltage regulator needs to be implement because 12v battery is not capable enough to charge battery phone and need to use DC-DC step down. An indicator was used to remind user when the battery run out of power. This type of portable solar generator can support small electrical appliance [8].

2.2.2 Development of a portable solar device

Development of a portable solar storage device is suitable for campers, hikers and climbers that need to charge their electronic gadget. This is because gadgets have been our part of routine to use in case of emergency, so the power will always be needed, although in a place that cannot get the electricity supply. This portable solar storage device only focus to DC supply. In this project, two types of solar panels were being experimentized to know the performance. The solar panels that were used are polycrystalline 12v and 18v. This experiment has been held to monitor the performance of solar panel. The results obtained from the experiment is that, 12V solar panel performance were greater than 18v solar panel due to the area of the solar panel [9] .

2.2.3 Behaviour of Households Towards Electricity Consumption: A Case Study At Seremban

The rapid economic and social growth has led to increasingly high energy demand in Malaysia following significant household energy consumption. Household energy consumption has contributed significantly to severe environmental problems. Substantial efforts have been made in research and development (R&D) on energy-efficient technologies to conserve household energy consumption and reduce environmental pressures. Reducing energy demand and improving energy efficiency are widely accepted, and least expensive. The behaviour of Households Towards Electricity Consumption Quick to reduce environmental stress and climate change. Although technological advancements are critical to increasing energy efficiency and promoting energy conservation, the commitment of electricity consumption factors has been recognized as significant for energy conservation. As indicated from the current findings, the mean score for willingness to buy energy-efficient equipment and willing to limit energy consumption electricity was moderate (M=5.22, SD=1.31 and M=5.66, SD=1.13, respectively). On the other hand, the households' willingness to reduce electricity consumption to preserve the environment is still high (M=4.71, SD=1.45). However, the households' interest in volunteering to raise awareness of electricity consumption and saving is moderate (M=4.71, SD=1.45). According to Teoh et al. (2020), while the public is aware of the solar energy option, they are unwilling to install solar photovoltaic panels due to the high installation costs and lack of information. Harms and Linton (2016) found that consumers are unwilling to buy energy-efficient electrical appliances due to high prices. In another study, they found that consumers' confusion and lack of information had hindered them from buying energy-efficient electrical appliances. Correspondingly, the households in the present study were found to have a low commitment to using energy-efficient equipment, which they considered costly. Other contributing factors were also their lack of information and environmental concerns. Those with significant environmental concerns would be more likely to buy energy-efficient appliances

When encouraged. Households' lack of commitment to utilizing energy-efficient technology can be attributed to several causes, such as high installation costs, ignorance, and environmental concerns. The high cost of energy-efficient appliances and the uncertainty brought on by incomplete knowledge may deter consumers from purchasing them. When encouraged, those who have serious environmental concerns are more inclined to buy energy-efficient products.

Improving consumer behaviour, disseminating knowledge, and offering incentives are crucial for encouraging energy conservation and lowering environmental stress, even though technological breakthroughs in energy efficiency are also necessary. The price of electricity for homes in Malaysia and the significance of energy-efficient equipment. It states that consumers can find and choose the most energy-efficient products with the use of the energy efficiency label, which has been approved by Malaysia's Energy Commission. Each appliance's energy efficiency is indicated by a star rating system that goes from one to five, with five stars denoting the highest level of energy efficiency. These gadgets not only help save money and cut down on electricity use, but they also lessen carbon emissions and enhance living standards. Appliances bearing the energy-star service mark use 20–30% less energy than what is required by federal regulations, according to Ward et al. (2011).

Aspects of home energy use such as knowledge, awareness, commitment, attitude, and behaviour are all examined in this study. Despite having concerns about the environment, the results show that families are not as committed to adopting energy-efficient appliances because of their higher cost when compared to non-energy-efficient options. On the other hand, it was discovered that household energy conservation is positively impacted by cost savings from government initiatives. [26]

2.2.4 Determinant Factors of Electricity Consumption for a Malaysian Household Based on a Field Survey

This study conducted a field survey on electricity consumption in Malaysian households to assess the determinant factors affecting electricity usage. The research focused on both technological and socio-economic perspectives, including building and appliance characteristics as well as socio-demographics and occupant behavior. The survey involved 214 university students and employed both direct and indirect questionnaire surveys from November 2017 to January 2018.The results, analyzed through multiple linear regression, indicated that appliance characteristics played a crucial role in influencing electricity consumption, with air conditioners, fluorescent lamps, and flat-screen TVs identified as the most impactful appliances. House characteristics were found to be the least significant in this context. Occupant behavior factors had a more substantial impact compared to socio-demographic factors. The study highlights the importance of considering technology-related aspects, such as specific appliances, when addressing electricity-saving strategies. The findings offer valuable insights for policymakers in Malaysia, suggesting a focus on targeted interventions related to high-impact appliances and occupant behavior to effectively reduce electricity consumption and combat increasing global CO^2 emissions.

Three regression models (single, double combined, and triple combined) were developed, revealing key insights. In the single model, appliance characteristics explained 43.4% of electricity consumption variance. The double combined models showed socio-demographic factors contributed more than occupant behavior, with air conditioners and fluorescent lamps being significant. Triple combined models indicated socio-demographic, appliance, and occupant behavior factors collectively explained 46% of variance, with air conditioners as the strongest contributor. Monthly income, number of air conditioners, and ownership of miscellaneous appliances were cross-correlated with household characteristics. Socio-demographic factors, such as monthly income and number of occupants, played a substantial role, with air conditioners, fluorescent lamps, and flat-screen TVs identified as key factors affecting electricity consumption.

Energy-saving air conditioners were recognized as effective in reducing electricity usage. Limited LED lamp ownership suggested room for improvement in energy-efficient lighting adoption. The study proposed policies promoting affordable LED lamps, scheduling air conditioner and fan usage, and enhancing energy-saving awareness in various settings. [25]

2.3 Concept of solar

The usage of solar energy will slow down the rate at which energy supplies are depleted and offers an alternative energy source that is free and unlimited. It also provides an alternative energy source that does not pollute the environment. The three most popular types of solar panels in the Malaysian market are the subject of this study, which also compares the performance of solar panel. Three panels that are most in used are monocrystalline, polycrystalline and thin film. Poly-crystalline solar panels are said to be the best appropriate for usage in Malaysia's environment [10].

Solar panels, also known as solar modules or photovoltaics (PV modules) function by converting solar energy into electricity directly through the photovoltaic effect of the semiconductor material in the panel [11]. The sun should radiate sunlight when the conditions are right. The two forms of solar radiation are diffuse radiation and direct radiation. Direct radiation occurs when the sun shines directly on the solar PV panel. Diffused energy radiation carries around 90% of the solar radiation. In other words, diffuse radiation happens when the sun's rays are filtered by elements including temperature, humidity, cloud cover, and other environmental circumstances. It mostly results from solar energy being directed into a cloud after being directed into a solar PV panel.

Energy radiation is the type of incoming radiation that our planet has repeated most frequently. Global radiation is the name given to this type of radiation in photovoltaic solar panels [10]. Solar technology is always accessible, pollution-free and environmentally friendly. Figure 2.1 shows the types of solar radiation.

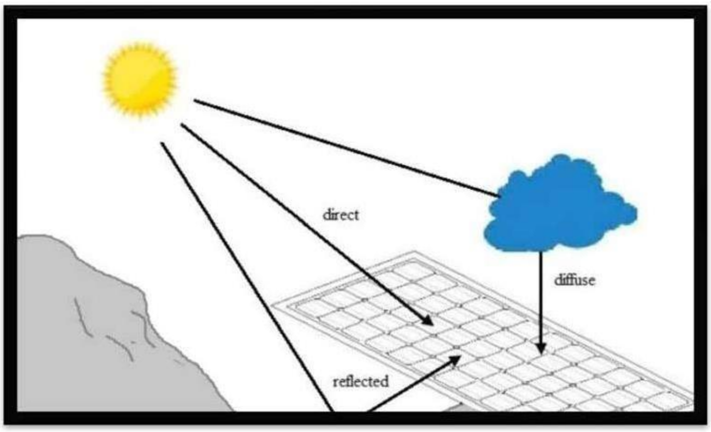

Figure 2.1 Types of solar radiation

2.3.1 Monocrystalline

One of the most effective solar panels is monocrystalline. Small bulk barriers are 0.5m to 10m with a thickness of cells between 100-200 m in monocrystalline silicon, which has a better efficiency due to its nature and a very low defect density of less than 1.0x1011 cm-3. This allows for more solar energy absorption. In contrast to a single silicon wafer, monocrystalline solar cells are composed of several smaller solar cells. The goal is to enable the solar cells to absorb solar energy at their highest possible efficiency. Solar cells store solar energy, which is later transformed into electrical energy [11]

2.3.2 Polycrystalline

Polycrystalline is one of the solar panels that is frequently employed. It is less effective than monocrystalline. However, polycrystalline usage is also extremely common. Many solar cells, one on each silicon wafer, are combined to create polycrystalline solar cells. Polycrystalline is only moderately effective. It possesses large bulk barriers larger than 0.5 mm to 10 mm and large defect densities of more than 1.0x1011 cm-3, with a cellthickness of 0.3 mm [11]

2.3.3 Comparison between monocrystalline and polycrystalline

Table 2.1 below shows the comparison between monocrystalline and polycrystalline. This comparison shows that monocrystalline is better than polycrystalline ineach aspects [11].

Table 2.1: Comparison monocrystalline and polycrystalline

Objective	**Monocrystalline**	**Polycrystalline**
Effect of voltage-current on time	√	
More efficiency	√	
Effect of power-fill factor on time	√	
Solar radiation	√	
Performance ratio	√	

2.4 A solar charge controller

In today's solar power systems, a solar charge controller needs to be installed to prevent overcharging and overvoltage which can reduce battery performance or lifespan, and may pose a safety risk. It may also prevent a battery from draining completely or perform controlled discharges, depending on the battery technology, to protect battery life. The solar charge controller converts solar energy into electricity. The electricity flow is measured by the charge controller, which is used to charge batteries. By charging the batteries and supporting the load using the solar energy, the solar charge controller saves electrical energy, resulting in the maximum solar power utilization during charging and backup mode [12].

There are two types of grid in solar system which are off-grid and on-grid. On-grid systems are connected to the electrical grid network to distribute electricity energy to customers while off-grid systems are solar panels that function separately from the electrical grid network. In order to maintain consistent voltage when using off-grid methods, batteriesmust be installed to store the electricity produced by solar panels during the day [13]. A charge controller has to be installed in off-grid or stand-alone system.

The most common charge controllers that are being used are series, shunt, PWM and MPPT. A series controller uses a type of control element connected in series between PV array and battery. This type of charge controller is widely used in small-scale PV systems, it can also be used for larger systems due to current limitations of shunt controllers. Shunt charge controller regulate battery charging from the PV array by short-circuiting the internal array to the controller. This type a charge controller that is mostly used to control the voltage or current to keep the battery from overcharging and deep discharge which causesthe battery to be damaged [14]. The most popular charge controller is PWM and MPPT. The pulse width of an oscillating circuit in a PWM charge controller is dependent on the batteryvoltage now. The pulse width is greater and the whole input solar energy is utilised to storethe battery if the battery voltage is lower. The MPPT will raise input voltage during the beginning stage while decreasing input current and reduce input voltage while increasing input current during peak hours. Energy is utilized to store batteries for backup systems [15].

2.4.1 Pulse Width Modulation (PWM)

The primary goal of pulse width modulation (PWM) is to replace the solar system controller power device with battery charging at constant voltage. With the use of PWM, modern charge controllers may consume less power while the battery is almost completely charged. PWM increases battery life by allowing the battery to be fully charged while putting

Less strain on the battery. The concept of PWM is that the voltage produced by a solar cell isthen detected by the voltage indicator. Following this measurement, a voltage controller regulates the voltage, and this voltage battery is therefore charged using a solar panel [16].When the battery voltage reaches the regulation set point, the PWM algorithm gradually reduces the charging current to avoid overheated and gassy, while charging continues to return the maximum amount energy to the battery as quickly as possible. The array voltage will be reduced to match the battery. Figures 2.2 shows the concept of PWM.

Figure 2.2 Concept of PWM charge controller

PWM is not a DC-to-DC transformer, but it is such a switch that connects the solar panel to the battery. When the switch is off, the voltage on the panel and the battery are almost the same volt. When on, the voltage will rise, indicating that the battery is being charged [17]. Table 2.2 shows the advantages and disadvantages of PWM charge controller. [17].

Table 2.2 The advantages and disadvantages of PWM charge controller

Advantages	Disadvantages
Cheaper than MPPT	Less efficient than MPPT
Small	Generates less output
Long life span	Cannot optimize for voltage differences and there is no load optimization
Smaller systems where there is less difference between solar panel output and battery voltage	Cannot used for larger systems and in situation where solar panel output is substantially greater than battery voltage

2.4.2 Maximum Power Point Tracker (MPPT)

MPPT charge controller is a charge controller that can increase solar panel efficiency by detecting the maximum solar radiation that enters the PV module. The systemwill begin functioning at Maximum Power Point (MPP) and generate its maximum power output. As a result, the system's overall cost is produced. A MPPT charging controller is used to get the most power possible out of the PV module so that the voltage on the PV module may produce its "maximum power point." Variations in maximum power are related to solar radiation, outside temperature, and solar cell temperature. MPPT, or maximum power point detection used to boost solar panels' performance [18].

A DC-DC transformer transforms power from a higher voltage to a lower voltage level, and the MPPT solar charge controller functions similarly. If the output voltage is less than the input voltage, the output current will be greater than the input current, maintaining the constant equation P=V*I. This equation suggests that power fluctuations also correspondto changes in voltage and current values [19].

2.4.3 Comparison between PWM and MPPT

The charge controller, which has the purpose of protecting the battery from deep draining and overcharging, is one of the factors that has the greatest impact on the system's quality and longevity. Based on the characteristics of the load, a charge controller may also draw the most power possible from the solar panel and transfer it there [20]. When the data from the two photovoltaic systems were compared, it became clearer that the MPPT controller was more effective than the internal PWM controller's longer working period. Additionally, it has been discovered that the efficiency charge controllers are unaffected by external factors. The comparison of these two controllers, however, identifies situations in which a PWM controller may be used in place of an MPPT controller in exchange for cost savings. The efficiency calculation of both charge controllers, the voltage and current variables of the battery and the solar panel is as follows [21].

$$Efficiency\,(\%) = (VBat \times IBat\ V/Panel \text{ x } IPanel) \times 100 \quad (1)$$

The power of polycrystalline solar panels is 30 W, with maximum power points of 18 V (Vmp) and 1.667 A (Imp). The batteries in both systems are acid-based. A lead AGM battery made by Magna with a nominal voltage of 12 V and a capacity of 18 Ah. A DC 6 W light controller is utilised as a load for MPPT, but for pwm load are used 4w because cannot deliver maximum power from solar.

The battery and solar panel voltage and current data are used to calculate the PWM charge controller's efficiency while it runs for five continuous hours. To examine the charging stage shift and test controller behavior under regular operating requirements, the experiment was done four times in a row. Additionally, incident solar radiation on the panel was measured using a pyranometer SP-110 from Apogee tool, and the temperature of the solar panel's surroundings was measured using a thermocouple UNIT-UT33C digital multimeter. Tests are run at temperatures higher than 35 °C. The average efficiency is computed after measuring the various variables during the PWM controller's implementation [21]. Table 2.3 shows a comparison between PWM and MPPT which resulted from the experiment[21].

Table 2.3 Comparison between PWM and MPPT

Experiment	PWM	MPPT
Efficiency	Low	Greater
Current delivered to the battery	Low	Greater
Current delivered to the load	Same	Same
Discharging	Low	Greater
Voltage variation	Low	Greater
Decreasing of battery	Low	Faster

2.5 Inverter

An inverter changes the voltage when converting DC to AC. It is a power adaptor, to put it another way. It makes it possible for battery-powered devices to operate regular appliances using regular house wiring. Grid interactive inverters are a different class of device. It is used to send excess energy back into the utility grid and to supply houses with grid connections with solar or other renewable energy. The inverter may be used in structures including homes, as well as in boats, recreational vehicles, and mobile applications.

Inverters should have a stamp of approval from an independent corporate testing facility, such as UL, ETL, CSA, etc. This is important to make sure the inverters are safely being used without any risk. There are two types of inverters frequently being used which are pure sine wave and modified sine. These two types of inverters are safe to be used. A good inverter is an industrial-grade product with a track record of dependability, safety certifications, and a long lifespan. The delicate parts of an inverter need to be adequately shielded against surges caused by static, lightning, and motor overloads as well as surges that return from those sources.

Additionally, overloads must be prevented. An unreliable appliance, bad wiring, or an excessive amount of load operating at once can all result in overloads. An inverter has to have a number of sensing circuits so that it can turn off if it can no longer effectively servicethe load. An inverter must be turned off if the DC supply voltage is too low because of a lowbattery charge or another flaw in the supply circuit. In addition to safeguarding the inverter and the loads, this also safeguards the batteries from over discharged damage [22].

2.5.1 Pure sine wave

Sine waves are clean, to put it simply. A sine wave's geometry is smooth by design.It is the best type of AC energy. The utility grid's generators create sine wave power, which then largely transmits to the consumer distortion-free. Compared to typical grid connections, a sine wave inverter may produce cleaner, more reliable electricity. The term "pure" may be used by the manufacturer to suggest little distortion. The inverter's specifications contain the information. Total harmonic distortion of a normal household should be less than 6 percent. Highly important electronics like in a recording studio requiresless than 3%. Other specifications are also crucial. The lights are kept constant via RMS voltage control [23].

2.5.2 Square sine wave

Despite producing a distorted square waveform that resembles the track of a pendulum being banged back and forth by hammers, a modified sine wave converter is less costly. In actuality, it is not even a sine wave. A modified sine wave is a false concept that was created by the advertising industry. Numerous electrical loads suffer negative consequences from the modified sine wave. It decreases the energy efficiency of transformers and motors by 10% to 20%. The excessive heat produced by squandered energy shortens the lifespan and decreases the dependability of motors, transformers, and other equipment, including certain appliances and computers. Some digital timing devices are confused by the waveform's choppiness. Surge protectors should not be utilized since they might overheat. In the 1980s, modified sine wave inverters were accepted, but since then, it have improved in efficiency and cost. Some people strike a balance by running their larger power tools or other sporadic heavy loads on a modified sine wave inverter while running their smaller, more regular and finer loads on a small sine wave inverter [23].

2.5.3 Comparison between pure sine wave and square sine wave

Based on the above explanations on the two types of inverters, Table 2.4 shows the comparison between pure sine wave and square sine wave inverter [23].

Table 2.4 Comparison between pure sine wave and square sine wave inverter

Feature	**Square sine wave inverter**	**Pure sine wave inverter**
Supported appliances	Motor	Laptop, oven, computer, refrigerator
Noise level	High because it creates humming noise	Normal
Safety of appliances	Less	High
Price	Economical	High
Efficiency	Less efficient	High efficient
Durability	Less durable	More durable

2.6 Sealed lead acid battery

Modern sealed lead acid batteries are made to work at their best within a limited range of conditions. In the past, water could be added to batteries to make up for the energy lost during overcharging owing to hydrolysis. The sealed lead acid battery is the most recentadvancement in lead acid batteries. The electrolyte used to make these batteries is used in very small amounts and is either kept in a gel or absorbed in the separator. The plates in themajority of sealed lead acid batteries contain calcium or other non-antimonial grid additionsto lessen gassing.

In comparison to flooded or maintenance-free systems, sealed lead acid batteries are also made to vent at greater internal pressures. This preserves the gases created during slight overcharging for later usage. Solar panel-powered closed-loop lead-acid battery charging should not go beyond its intended working range. When a sealed lead-acid battery is charged outside of this range, the positive plate's limited service life might experience rapid deterioration.

The earliest surgical outcomes from batteries recovered from the field show that a battery with no maintenance lasts around 60% longer than an equivalent sealed-size independent lead acid battery. An anticipated service life of 6 years has been determined fora maintenance-free lead-acid battery in this application. In comparison to the far more complicated closed lead acid technology, this battery is also less expensive [24].

2.7 Summary

This chapter discussed the existing solar generator which is related to this project. This project is about portable solar generator. All of the suitable components have been researched to make sure the components that will be used to carry out this project are suitable to be used in Malaysia based on the past studies. Types of solar panel also have been studied to know which solar panels are most efficient to generate power. Types of charge controllers also have been researched to make sure which type of solar charge controllers that will be suitable for this project. Inverters are also important to make sure which type of inverter that good for electrical load. From the research of the battery, the modern sealed lead acid worth tobe used.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter primarily focuses on design and development techniques to be employed in this project. The components of this project's hardware and software will be proposed. Several elements need to be examined and set up properly to guarantee the project's success. To ensure the methodology is better understood, this chapter will generallybriefly the outline of the project's development using flowcharts and block diagrams.

3.2 Methodology

The proposal offers control charging using independent solar panels that are completely equipped. Several aspects will be merged to accomplish the charging control function using solar energy. The system is created incrementally, starting with the research, then moving on to hardware, software, and eventually data collecting. The methodology, tools, and software employed are all described in this chapter. The whole project development flowchart is shown in Figure 3.1.

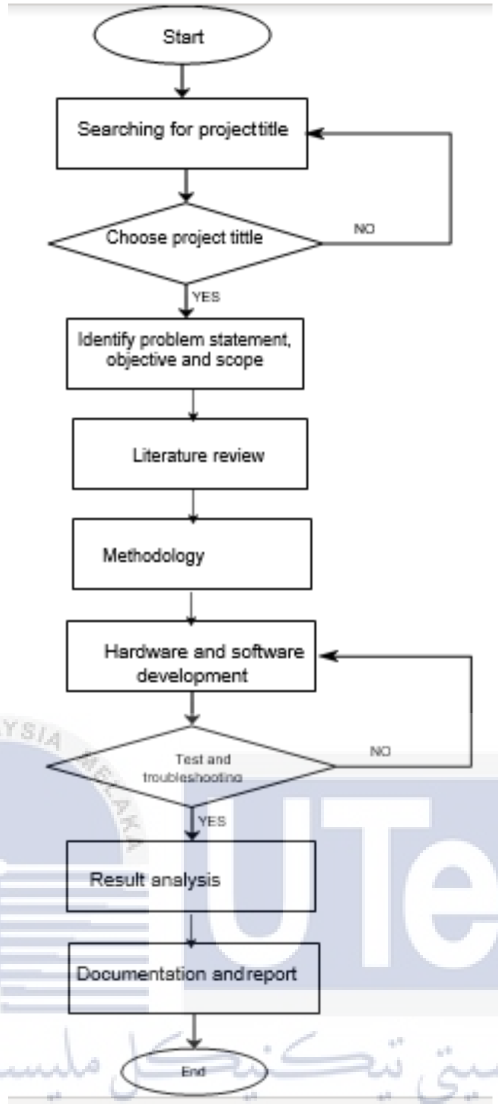

Figure 3.1 Flowchart of the project development

3.3 Block diagram of standalone PV solar with inverter

The solar panel will receive energy from sunlight and convert DC electricity. And battery will store energy received from sunlight but will monitored by the solar charge controller. Inverter is to convert AC to DC as shown in Figure 3.2.

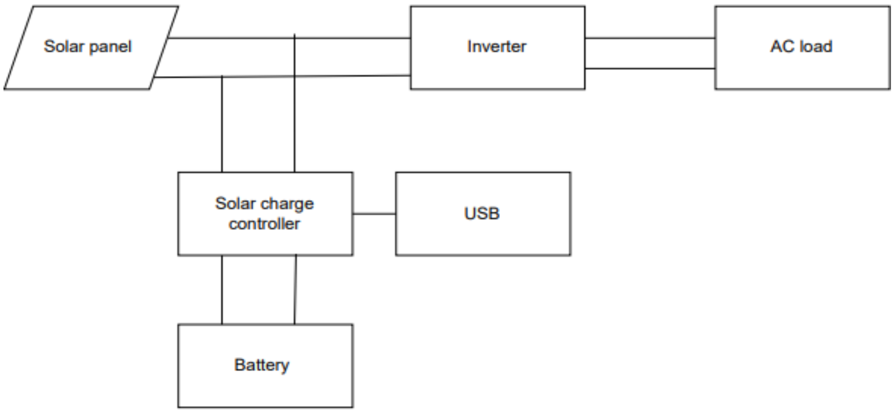

Figure 3.2 Block diagram of standalone PV solar with inverter

3.4 Block diagram of the overall system

As shown in Figure 3.3 below, the solar panel supply through a charge controller and will be monitored if the battery is full. DC load can use directly from the charge controller. The battery will store the power that generates from solar panels. Inverter converts DC to AC supply 240/50 Hz.

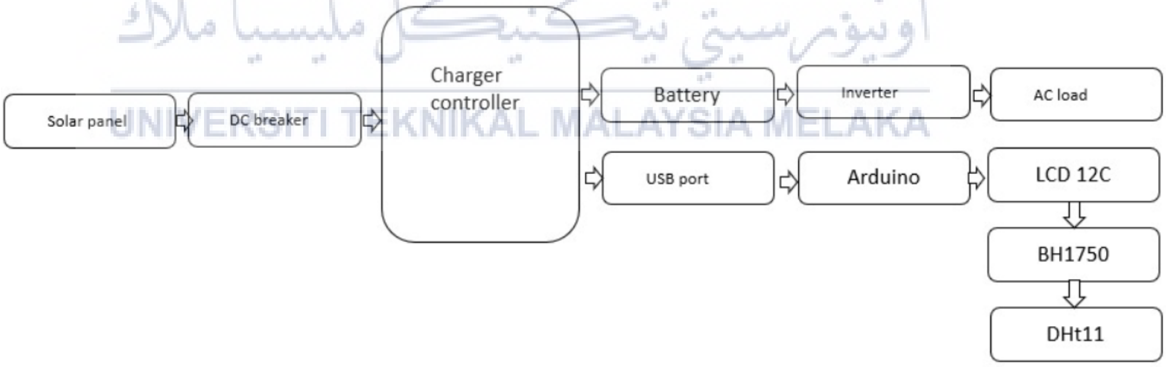

Figure 3.3 Block diagram

3.5 Development of software

The Software development is required for this project to ensure that the system functions properly. The software required to build circuit diagram sketching for hardware functions.

3.5.1 Proteus Software

Without requiring actual prototypes, Proteus simulation as in figure 3.4 offers a way to comprehensively evaluate the performance and functionality of circuits. Proteus is notable for its ability to easily replicate analogue and digital systems.

Figure 3.4 Proteus software

3.6 Development of hardware

The PV system serves as the project's input and produces energy for the entire system. Consequently, to guarantee the system's efficiency and consistency, the system's performance prioritizing developed PV systems is necessary. As it is the primary element affecting the performance of the PV system, several factors should be taken into consideration. Figure 3.5 shows the solar PV system

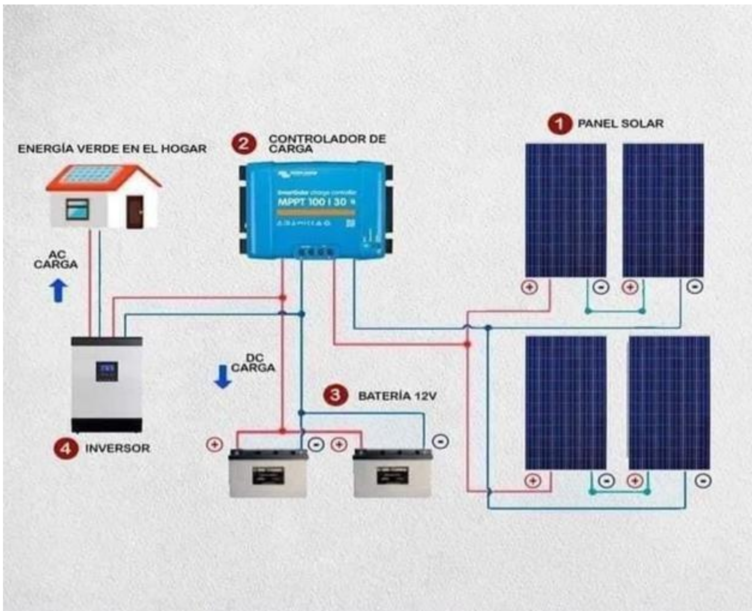

Figure 3.5 PV system

3.6.1 Solar panel

The solar panel is the most important hardware to supply power in this system. Solar panels come in a variety of sizes, output power, costs, and other characteristics. This is important to supply enough energy for a generation. It is very important to choose the right solar panel to get a good system. Figure 3.6 shows polycrystalline solar panel that will be used in this project.

Figure 3.6 Polycrystalline solar panel

Among the aspects of solar panel selection is due to the efficiency of the solar panel. Polycrystalline solar panel efficiency is suitable to use at Malaysia due to the weather. The efficiency of polycrystalline solar panel is moderate which is between 13%- 16% with moderate efficiency, thus, it will produce more energy for each square foot.

3.6.2 Battery

The battery that were used is a Rechargeable Sealed Lead Acid Battery. This is because this battery can be recharged when the power is reduced. This battery has also been used for solar projects and this proved that this battery is suitable for the use of PV systems. This battery is free maintenance and has less impact on the environment. Figure 3.7 below shows the type of battery that will be used in this project.

Figure 3.7 Sealed Lead Acid Battery

3.6.3 Inverter

Inverter, as shown in Figure 3.8 is a component that converts DC to AC. This deviceis important to convert DC to AC which is a DC supply generated from solar. An inverter monitors power from the solar panel and converts it to an AC electricity.

Figure 3.8 Inverter

3.6.4 PWM charge controller

The pulse width of an oscillating circuit in a PWM charge controller is dependent on the battery current voltage. The pulse width is greater and the whole input solar energy is utilized to store the battery if the battery voltage is low. The most popular charge controlleris PWM and MPPT. For this project, a PWM charger controller will be used, as shown in Figure 3.9.

Figure 3.9 PWM Charge Controller

3.6.5 Solar DC breaker

DC breaker is an important device to be installed. It is important to protect other devices from getting damage by safely opening the circuit. Solar DC breaker is placed between the solar charge controller and battery. The thermal trips the breaker when the current exceeds the rated value. The bimetallic contact will heat up and expand because the current produces more heat. Figure 3.10 shows the DC breaker which will be used in this project.

Figure 3.10 DC breaker

3.6.6 DC wire

AC cable and DC cable are different. AC cable can be installed to a frequency in industrial. But DC cables are used in rectified DC transmission. The DC cable is utilized in locations like solar panels or batteries where electricity is generated on-site. Due to their frequent use in outdoor applications, DC cables are often doubly insulated. DC cables are more capable of transporting current than AC cables. Figure 3.11 shows the type of DC wire

Figure 3.11 DC wire

3.6.7 BH1750 sensor

The ambient light intensity is measured using the digital light sensor bh1750. It is often utilized in many different applications, including energy-saving systems, automated lighting management, and display backlight control. The sensor provides precise measurements of light intensity by utilizing an integrated analog-to-digital converter. It is small, simple to operate, and has an I2C (Inter-Integrated Circuit) interface for communication with microcontrollers and other devices. Figure 3.12 shows the type of bh1750 sensor

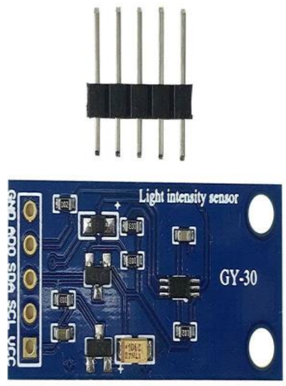

Figure 3.12 BH1750 sensor

3.6.8 Dht11

A simple, incredibly affordable digital temperature and humidity sensor is the dhT11. It measures the air around it using a thermistor and a capacitive humidity sensor before emitting a digital signal on the data pin. Figure 3.13 shows the type of dht11 sensor.

Figure 3.13 DHT11 sensor

3.6.9 Main switch

A switch or other device that manages the primary power source of a system or electrical circuit is sometimes referred to as having the mainswitch function. Users may conveniently manage the flow of energy and maintain safety when working with electrical equipment by turning the power on or off using the main switch. Users may quickly turn on or off the power supply to the associated devices or circuits by flipping the main switch. Figure 3.14 is an example for main switch.

Figure 3.14 Main switch

3.6.10 Residual Circuit Breaker

RCCB stands for Residual Current Circuit Breaker. This type of electrical safety device protects against the possibility of fire and electrical shock caused by ground faults or leakage currents. Any imbalance in the electrical currents entering and exiting a circuit is monitored by RCCBs. When the RCCB senses a flaw or leakage current, which indicates that current is flowing via an unapproved channel (such a person or a broken appliance), it quickly breaks the circuit, cutting off the power supply and preventing harm. RCCBs are often used in residential, commercial, and industrial electrical systems to increase safety. Figure3.15 show the RCCB

Figure 3.15 Residual Circuit Breaker

3.6.11 Miniature Circuit Breaker

The acronym for Miniature Circuit Breaker is MCB. This type of switch protects electrical circuits against overcurrents and short circuits. Main function of an MCB is to automatically turn off the electrical flow upon reaching a certain limit or in the event of a short circuit. As a result, there is a decreased risk of electrical fires and damage to appliances, other linked equipment, and electrical wiring. MCBs are available in a range of current ratings and trip characteristics to suit different applications and load needs. They are often found in electrical distribution panels or consumer units, and they may be manually reset after tripping. Figure 3.16 shows the picture of mcb.

Figure 3.16 Miniature Circuit Breaker

3.7 Tools

To measure the input and output power in each project component, a few tools were employed in this project. To guarantee that the system's equipment is compatible, measurements are made to obtain exact data and read specific values.

3.7.1 Multimeter

A multimeter is an instrument that can measure current and voltage. Multimeter comes in two types, which are analog and digital. For analog multimeters, it is suggested to calibrate to prevent errors while measuring. It can measure in AC or DC by changing the mode. To measure the voltage, connect the probe parallelly to the circuit or component which is needed to be measured. The voltmeter will connect two points across the circuit and the result shown is the measured voltage of the given circuit. To measure the current, change the mode to measure current, then the probe must connect in series to the circuit or equipment that requires measuring. Figure 3.17 shows the digital multimeter that will be used in this project.

Figure 3.17 Digital Multimeter

3.8 Specification of solar panel

Load details:

1 no fan of 20W use for 4 hour/day

1 no of 6W led light use for 4 hour/day 1 no of 5W charger use for 2 hour/day

Total load = (1 x 20W x 4) + (1 x 6W x 4) + (1 x 5W x 2) = 114W

System-specific requirement:

Energy usage (per day) = 114Wh

Depth of Discharge (DoD) = 50%

Days of Autonomy

(DoA) = 2 day

Battery Bank Temperature Multiplier (BBTM) = 1

Peak Sun Hour (PSH) = 4 hours

Solar panel size:

The output power of solar panel

= Energy usage (per day) ÷ PSH ÷ system efficiency

= 114Wh ÷ 4 hours ÷ 0.85

= 33.5W

Monocrystalline panel size = 12V, 35W

Hence, 1 monocrystalline solar panel is needed for the system to operate.

3.9 Specification of battery bank

Average daily:

Energy usage (per day) = 114W

Battery bank capacity (Wh):

= (Daily average usage x DoA x BBTM) ÷ DoD

= (114Wh x 2 days x 1) ÷ 0.5

= 456Wh

Battery bank capacity (Ah):

= Battery bank capacity (Wh) ÷ system voltage

= 456Wh ÷ 12V

= 38Ah, 12V

Sealed Lead Acid battery size = 38Ah, 12V

Hence, this project needs only 1 battery of Sealed Lead Acid.

Summary of system sizing:

1. Energy usage: 114W, 1 day
2. Solar panel size: 12V, 35W x 1 solar panel
3. Battery size: 38Ah, 12V
4. Depth of Discharge: 50%
5. Days of Autonomy: 2 days

3.10 Calculation

The electrical power formula is used to obtain the value of power generated by the solar panel. The relationship between the solar panel power, voltage, and current is shown in Equation 4.1. Meanwhile, the battery charging time data has been obtained by referring to Equation 4.2.

$$\boldsymbol{P = VI} \tag{4.1}$$

Where P = Solar panel power (W)

V = Solar panel voltage (V)

I = Solar panel current (A)

$$T = \frac{C}{R} \tag{4.2}$$

Where T = Battery bank charging time (Hours)

C = Battery bank capacity (mAh)

R = Charging current (mA)

3.11 Sustainable development

The practise of employing a variety of techniques and methods to make sure that the generator can provide clean, renewable energy while simultaneously reducing its environmental effect is known as sustainable development for portable solar generators. This entails choosing energy-efficient appliances, keeping the generator in good working order,and appropriately disposing of it when it has served its purpose. The portable solar generator is a potential long-term option for powering devices in a range of contexts since sustainable development assures that it can continue to run effectively without using natural resources or damaging the environment. We can contribute to the building of a more sustainable future that benefits both people and the environment by embracing sustainable development practices

3.12 Summary

This chapter describes the proposed methodology and design of the project. The operation of the processing system has been demonstrated by a flowchart and a block diagram that describe the procedures. The hardware and software that will be used in this project have also been highlighted with some justifications for its implementation. Sustainable development with regards to renewable energy has been stated. Finally, this chapter also highlights the task and activities that will be carried out throughout the duration of accomplishing the project.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The outcomes of the development of the portable solar generator for distant use are documented and discussed in this chapter. The project's anticipated outcome will be centered on the PV system's electricity generation as well as the system's efficiency. The initial phase of project planning will mostly rely on theories and research to reach the basic outcome. This chapter's findings will show how well the PV system created for this project performed and whether or not it was able to make the entire system self-sufficient. Additionally, a record of the system's accuracy will be kept. After that, the data will be further examined to see how well it performed in minimizing power waste.

4.2 Project prototype

The project's prototype is constructed using all of the selected tools and equipment using the research conducted in Chapter 2 and the computations and simulations completed in Chapter 3. The carefully selected hardware, such as the inverter, solar panel, battery bank, solar charge controller, and so, on are put together in accordance with the results of the circuit simulation completed in Chapter 3.In addition, all of the tools and programs listed in Chapter 3 are used for the software's design and coding. To meet the needs of the system, the software design is tested and adjusted several times. The project prototype's configuration and design are documented as follows.

4.2.1 Hardware installation

The project's 37 cm by 41.5 cm wooden prototype was created from pallet wood. The solar panel was placed to collect daylight during the working day. The solar charge controller, which regulates the quantity of energy entering the system, is connected to the solar panel's output are to analyze the solar panel, a loop involving a bh1750 sensor and dht11 sensors is used while voltage and current are measured manually by using a multimeter. The solar charge controller may direct generated power to be stored in the battery bank or receive electricity from the battery bank when needed because its second port is connected to the battery bank. The inverter that changes direct current into alternating current to power home appliances is linked to the solar charge controller's output connector. The hardware installation is as the project prototype's front, right side, and top views are depicted in Figures 4.1 to 4.4.

Figure 4.1 (Prototype) Front

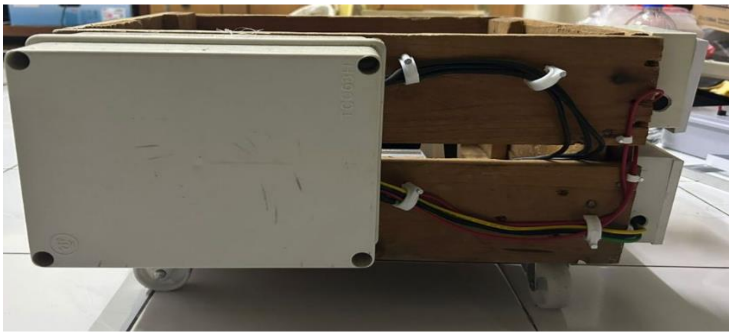

Figure 4.2 (Prototype) Right Side

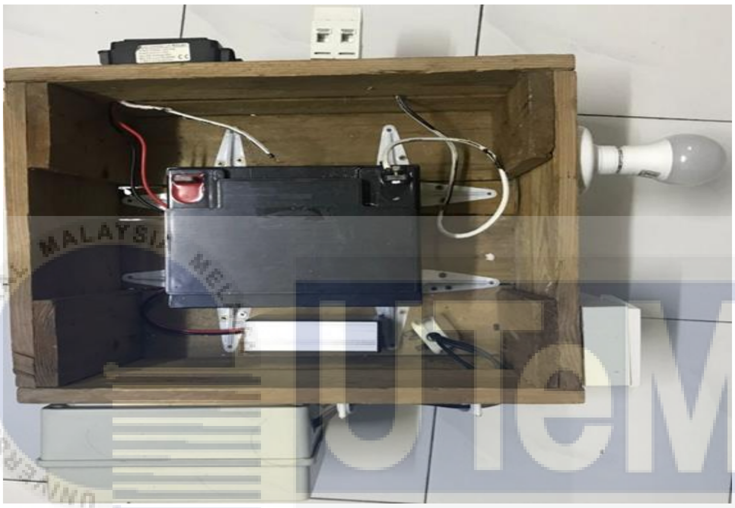

Figure 4.3 (Prototype) Top

Figure 4.4 (Prototype) Left side

4.2.2 Software Development

The software designed for this project involves, which are the coding setup for the microcontroller. In the development of the system, the coding for commanding the function of the system is done by using Arduino IDE and uploaded to the Proteus 8 for simulation purposes. Then the final coding that ensures the system is functioning is uploaded to the Arduino UNO.

4.3 Experiment Test And Protocol

To guarantee the accuracy of the findings, the system's performance has been tested for a number of days in a row. First, the solar panel's performance is evaluated for 12 hours every day for six days in a row. In order to determine if the system can function independently throughout the battery life cycle, the efficiency of the battery capacity for powering the entire system has also been examined. In the course of the trial, the solar panel has been exposed to the elements to obtain complete sunlight. A solar charge controller that was fastened to the battery bank received the solar panel's output. A 100W inverter that was connected to the load is subsequently connected to the battery's output. Every day for the last eight hours, mostly at night, the load has been engaged.

4.3.1 Calculation

For the last six days, this procedure has been carried out again. During the data collection, the electrical power formula is used to obtain the value of power generated by the solar panel. The relationship between the solar panel power, voltage, and current is shown in Equation 4.1. Meanwhile, the battery charging time data has been obtained by referring to Equation 4.2.

$$P = VI \tag{4.1}$$

Where P = Solar panel power (W)

V = Solar panel voltage (V)

I = Solar panel current (A)

$$T = \frac{C}{R} \tag{4.2}$$

Where T = Battery bank charging time (Hours)

C = Battery bank capacity (mAh)

R = Charging current (mA)

4.3.2 PV Solar System On Day 1

Table 4.1 shows the data obtained from the standalone PV solar system on 11/12/2023. The weather was uncertain on that day sometimes it was sunny while other time were cloudy.

Table 4.1 The result of data collection for day 1

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)	Temperature	Irradiance
7 am	17.3	0.33	5.709	12	121.21	29	91.44
8 am	18.2	0.59	10.738	12	67.8	29	146.81
9 am	18.8	0.72	13.536	12	55.6	30	218.69
10 am	20.7	1.51	31.257	12	26.5	34	401.44
11 am	19.7	1.15	22.6	12	34.8	33	395.39
12 pm	17.8	0.29	5.162	12	138	28	109.66
1 pm	15.9	0.1	1.59	12	400	26	71.44
2 pm	20.1	1.16	23.36	12	34.5	37	371.13
3 pm	20.1	1.02	20.502	12	39.2	35	292.15

4 pm	17.6	0.27	4.572	12	148.15	29	85.13
5 pm	18.1	0.44	7.964	12	91	30	123
6 pm	18.9	0.98	18.52	12	40.8	31	207.95
7 pm	15.9	0.09	1.431	12	444.44	30	63.54

Based on Table 4.1, the solar panel generated the lowest power at 7 pm with a value of 1.431 W with the irradiance at 63.54 as the sun was getting set. In comparison, the power generated by the solar panelat 10 am is the highest recorded, with a value of 31.257 W. The power dropped at noon as the weather started to rain and cloudy in the evening.

4.3.3 4.3.3 PV Solar System On Day 2

Table 4.2 shows the data obtained from the standalone PV solar system on 12/12/2023. The weather recorded that day was sunny in the morning and cloudy in the evening.

Table 4.2 The result of data collection for day 2

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)	Temperature	Irradiance
7 am	17.5	0.39	6.825	12	102.6	27	162.48
8 am	18.1	0.53	9.6	12	75.5	29	234.97
9 am	19.4	0.84	16.3	12	47.6	30	325.33
10 am	20.5	0.90	18.5	12	44.4	30	344.93
11 am	21.1	2.33	49.2	12	17.2	34	415.39
12 pm	21.6	2.37	51.2	12	16.9	28	431.44
1 pm	21.1	3.05	64.4	12	13.1	41	431.44
2 pm	21.1	2.27	47.9	12	17.6	45	418.13
3 pm	20.8	1.26	26.2	12	31.7	40	247.71
4 pm	20.6	0.92	19	12	43.5	38	431.44
5 pm	19.2	0.3	5.76	12	133	36	131.44

6 pm	20.1	0.94	19.7	12	42.5	31	287.95
7 pm	15.3	0.03	0.46	12	1333.3	30	53.58

Based on Table 4.2, the lowest power generated by the solar panel was at 7 pm with an irradiance at 53.58 value of 0.46 W. The power generated by the solar panel at 1 pm is the highest recorded,with a value of 64.4 W and an irradiance of 431.44. The power dropped at 5 pm because the irradiance is disappeared slowly.

4.3.4 PV Solar System On Day 3

Table 4.3 shows the data obtained from the standalone PV solar system on 13/12/2023. The weather condition recorded uncertain on that day sometime are sunny while others are cloudy.

Table 4.3 The result of data collection for day 3

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)	Temperature	Irradiance
7 am	17.5	0.09	1.6	12	444.4	27	161.89
8 am	18.8	0.82	15.4	12	48.8	29	252.69
9 am	19.6	1.73	34	12	23.1	30	321.5
10 am	20.5	2.18	44.7	12	18.3	34	343.12
11 am	19.5	0.88	16.28	12	45.5	35	192.43
12 pm	17.1	0.21	3.5	12	190.5	28	119.20
1 pm	18.5	0.56	10.36	12	71.4	28	125.97
2 pm	20.1	0.88	17.7	12	45.5	30	121
3 pm	19.1	0.5	9.55	12	80	30	135.64
4 pm	19.1	0.58	11.1	12	69	29	131.2
5 pm	19.1	0.35	6.7	12	114.3	30	337.8

6 pm	20	0.98	19.6	12	40.8	31	287.95
7 pm	15.9	0.03	0.477	12	1333.33	30	53.58

Based on Table 4.3, the solar panel generates the lowest power at 7 pm with a value of 0.477 W with the irradiance 53.58. The power generated by the solar panel at 10 am is the highest recorded on that day, with a value of 44.7 W with an irradiance 343.12. Then, the power dropped at 11 am and onwards due to the cloudy weather.

4.3.5 PV Solar System On Day 4

Table 4.4 shows the data obtained from the standalone PV solar system on 14/12/2023. The weather conditions recorded on the morning was cloudy but after 1 pm the weather was sunny.

Table 4.4 The result of data collection for day 4

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)	Temperature	Irradiance
7 am	17.8	0.13	2.3	12	307.7	29	167.73
8 am	20	0.34	6.8	12	117.6	29	189.97
9 am	20.1	0.36	7.2	12	111.1	30	195.72
10 am	20.1	0.49	10	12	81.6	31	203.64
11 am	20.1	0.98	20	12	40.8	31	358.72
12 pm	20	0.76	15.2	12	52.63	31	338.84
1 pm	20	0.75	15	12	53	32	327.13
2 pm	21.2	2.21	46.8	12	18.1	35	431.44
3 pm	21.4	2.58	55.2	12	15.5	44	431.44
4 pm	21.2	2.33	49.4	12	17.2	38	431.44
5 pm	21.2	2.91	61.7	12	13.7	50	431.44
6 pm	19.6	0.34	6.7	12	117.6	31	263.66
7 pm	17.1	0.08	1.4	12	500	29	52.97

Based on Table 4.4, the solar panel generates the lowest power at 7 pm with a valueof 1.4 W with irradiance 52.97. The power generated by the solar panel at 5 pm is the highest recorded, with avalue of 61.7 W with the irradiance 431.44. Then, the power dropped at 6 pm onward due to sunrise is set.

4.3.6 PV Solar System On Day 5

Table 4.5 shows the data obtained from the standalone PV solar system on 15/12/2023. The weather condition recorded on that day was sunny during the experiment data was taken.

Table 4.5 The result of data collection for day 5

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)	Temperature	Irradiance
7 am	16.9	0.05	0.8	12	800	29	117.73
8 am	19.5	1.2	23.4	12	33.3	29	289.97
9 am	19.6	1.73	34	12	23.1	31	295.72
10 am	21	2.18	45.8	12	18.3	34	403.64
11 am	20	1.05	21	12	38.1	30	228.72
12 pm	21.5	2.44	52.5	12	16.4	36	431.44
1 pm	21.5	2.51	54	12	16	39	431.44
2 pm	21.1	2.21	46.6	12	18.1	35	431.44
3 pm	21.5	2.61	56.1	12	15.3	48	431.44
4 pm	21.2	2.33	49.4	12	17.2	35	431.44
5 pm	20.3	1.25	25.3	12	32	32	401.83
6 pm	18.3	0.59	10.8	12	67.8	30	259.92
7 pm	17.9	0.1	1.79	12	400	30	52.97

Based on Table 4.5, the lowest power generated by the solar panel was at 7 am with a value of 0.8 W with an irradiance 117.73. The power generated by the solar panel at 3 pm is the highest recorded, with a value of 56.1 W with an irradiance 431.44. Then, the power dropped at 5 pm and onwards due to sunrise is set.

4.3.7 PV Solar System On Day 6

Table 4.6 shows the data obtained from the standalone PV solar system on 16/12/2023. The weather conditions recorded on that day were sunny for the whole day.

Table 4.6 The result of data collection for day 6

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)	Temperature	Irradiance
7 am	18.3	0.62	11.35	12	64.5	29	199.61
8 am	19.5	1.1	21.45	12	36.36	30	297.97
9 am	19.6	1.72	33.712	12	23.25	30	312.50
10 am	20	1.96	39.2	12	20.4	31	403.64
11 am	20	1.55	31	12	25.8	35	431.44
12 pm	21.0	2.44	51.24	12	16.4	38	431.44
1 pm	21.0	2.50	52.5	12	16	41	431.44
2 pm	21.4	3.24	69.34	12	12.35	49	431.44
3 pm	21.5	3.36	72.24	12	12	50	431.44
4 pm	21.5	3.46	74.4	12	11.56	53	431.44
5 pm	20.2	2.41	48.68	12	16.6	45	431.44
6 pm	20	1.22	24.4	12	32.8	31	431.44
7 pm	17.9	0.16	2.864	12	250	30	59.97

Based on Table 4.6, the solar panel generates the lowest power at 7 pm with a value of 2.864 W with an irradiance 59.97. The highest power generated by the solar panel recorded at 4 pm was 74.4 W with an irradiance 431.44. Then, the power dropped at 5 pm due to the sunrise being set.

4.4 Standalone PV Solar System Average Data Analysis

The result obtained from the experiment has been analyzed and calculated to get the average data value. The average output of solar panel voltage, current, power, battery voltage, charging time, temperature, and irradiance data for the 6 days are shown in Table 4.7 below.

Table 4.7 The average data obtained from the standalone solar system for 6 days

Day	Average					
	Solar Panel Output Voltage (V)	Solar Panel Output Current (A)	Solar Panel Output Power (W)	Battery Charging Time (Hours)	Temperature	Irradiance
1	18.3	0.66	12.94	126.3	30.8	198.29
2	19.72	1.24	26	147.61	33.8	301.25
3	18.8	0.75	14.7	194	30.07	198.77
4	18.4	1.1	22.9	111.3	33.84	294.16
5	20	1.56	32.4	115.04	33.7	323.67
6	20.1	1.98	41	41.38	37.84	349.63

From table 4.7 the highest power output is on day 6. The power output that has been measured were depends on the voltage and current of the pv solar panel. The irradiance affecting the output of the solar panel. The more the irradiance can solar panel get, the more the power output solar panel can get. Meanwhile the surrounding temperature also affecting the performance of solar panels, if the temperature were not suitable for solar panels, the output that will get will be less efficient. But from an experiment the solar panel can work efficiently even though the surrounding temperature is high

Figure 4.5 illustrates the graph of the relationship between the average solar panel power and average solar panel current. According to this graph in Figure 4.5, the average solar panel power increases as average solar panel current increases. An irradiance also plays a full role to get higher current

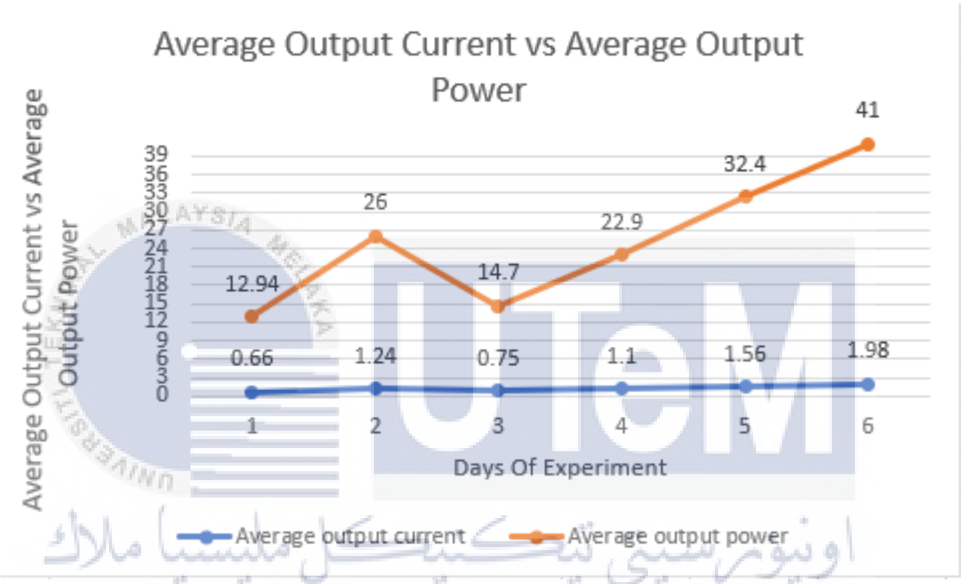

Figure 4.5 Graph of the relationship between average solar panel current and average solar panel power

Based on table 4.7 also, the prototype testing for the solar panel project is scheduled to take place during the rainy season in Malaysia. This introduces uncertainty in the 6-day average intensity of solar radiation. The weather conditions over the past month have been predominantly gloomy and rainy, leading to significant variations in the data collected each day.

Additionally, the suggested size of the solar panel is another factor contributing to the uncertain output current. The solar panel PV sizing calculation in Chapter 3 specifies a peak sun hour of 4 hours, assuming the experiment will be conducted on a bright sunny day.

However, on the day of testing, the weather was cloudy on most of the affected the output of the PV solar panel. On a sunny day, the proposed 50 W, 18 V PV solar panel is expected to produce a maximum current output of 2.77 A. It should be noted that the PV solar panel's output current will be at its minimum in overcast weather and at its maximum according to the panel's specifications. As a result the solar panel ability to convert more sunlight into electricity is achieved. Based on the experimental data obtained, the highest average output power produced by the solar panel is 41 W,with an average output current of 1.98 A.

The charge controller plays a crucial role in charging a sealed lead acid battery. Its primary function is to regulate the charging current, ensuring that the battery bank is protected from overcharging and over-discharging. According to the experimental data in Table 4.8, it took a considerable amount of time, more than 24 hours, for the battery bank to fully charge. This extended charging time can be attributed to the 50 W solar panel being used. Based on calculations in section 3.8 in chapter 3, it is recommended to use a minimum power of 33.5 W for the solar panel. Increasing the wattage of the solar panels can potentially decrease the charging time, but this is also dependent on weather conditions.

Figure 4.6 shows the relationship between the average solar panel current and battery bank charging time. According to the graph in Figure 4.6, the average charging time of a battery bank decreases as the average solar panel output current increases. This relationship indicates that the higher the output current produced by the solar panel, the less time it takes for the battery bank to charge fully.

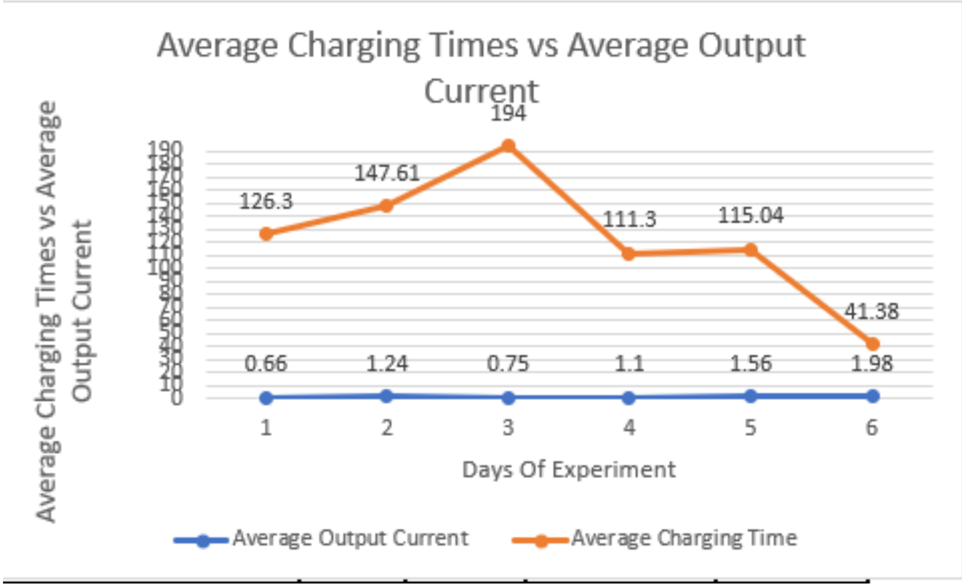

Figure 4.6 Graph of the relationship between the average battery bank charging time and average solar panel current

In Figure 4.6, the lowest current is observed on day 1, while the highest charging time to fully charge the battery bank occurs on day 3. These variations are linked to weather changes. When irradiance is low, the output current decreases, leading to an extended charging time. Figure 4.7 illustrates the average irradiance versus average power relationship. The sunlight's irradiance influences the solar panel's output power, reaching its maximum when irradiance is high. Consequently, greater irradiance results in an increase in the power generated by the solar panel.

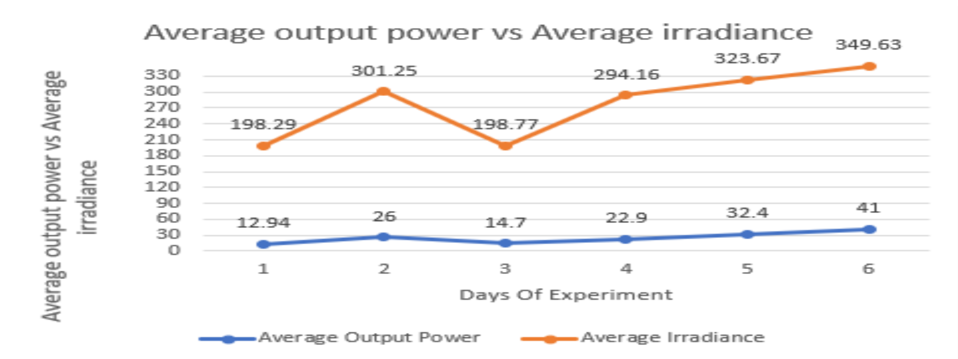

Figure 4.7 Graph of the relationship between the average power time and average irradiance

From Figure 4.7 the highest irradiance occur at day 6. When the irradiance is high the power output produced from the solar panel will increase. The power output of the solar panel depends on the irradiance from the sunlight. The lowest irradiance is at day 1 so that the power output of the solar panel is the lowest at day 1. This is because on that day the weather was cloudy. so there is a shaded area on the solar panel. The irradiance of the sunlight also becomes low because the sky is cloudy.

In addition, the battery's endurance has been considered and analyzed to ensure that the battery bank can power the load at its maximum capacity. The battery endurance of the battery bank is the maximum amount of time it can support the load by itself. The battery bankendurance is obtained using the formula (4.3) shown below.

$$Battery\ Bank\ Endurance = \frac{V_{dc} \times Ah}{load} \tag{4.3}$$

The battery endurance can be determined by using the battery's specifications in this project. Assuming the capacity of the battery is at its optimal capacity,

$$Battery\ Bank\ Endurance = \frac{12\ V \times 40\ Ah}{31\ W} \tag{4.4}$$

$$Battery\ Bank\ Endurance = 15.48\ Hours$$

Referring to (4.4), theoretically, the battery bank can power the system for up to 15.48 hours. Usually, the efficiency of any battery bank is only around 85% of its claimed specification. Therefore, the actual battery endurance is considered as below.

$$Battery\ Bank\ Endurance = \frac{12\ V \times 40\ Ah}{31\ W} \times 85\% \tag{4.5}$$

$$Battery\ Bank\ Endurance = 13.16\ Hours$$

Based on equation (4.5), the actual battery bank endurance is 13.16 hours with a capacity loss of around 6 Ah. However, during testing, the battery bank could only power the system for 12 hours and 40 minutes if all loads were used altogether. The battery bank is supposed to be able to power the load for up to 13 hours, as targeted. However, according to the 40 Ah sealed lead acid battery specification, the battery has a cutoff voltage range of approximately 11 V to 11.5 V. The battery bank will stop discharging when the battery bank voltage reaches its cut-off voltage. Thus, the 40 Ah sealed lead acid battery type was suitable to be used as a battery bank in this project due to its specifications.

4.5 Performance Analysis of Solar Generator

This project uses solar as the primary source of energy, and the battery serves as the storage for the energy generated by the solar panel. To protect the battery from overcharging, a solar charge controller is used. This helps prolong the lifespan of the battery. However, the sealed lead acid battery used has a cut-off voltage of 11.5 V. The power output generated by the solar panel depends on the irradiance emitted by the sun. If it is a cloudy day, the output power produced by the solar panel will be slightly lower. The higher the irradiance, the higher the output power generated by the solar panel. The sensor used to measure irradiance is the BH1750, which helps users find suitable locations to place the solar panel for maximum output power. The DHT11 is used to measure the ambient temperature to monitor the surrounding temperature. Figures 4.8 shows a multimeter that is used to measure the voltage and current manually. Figure 4.9 shows the temperature and the irradiance value measured by using bh1750 and dht11

Figure 4.8 Measured voltage and current manually using a multimeter

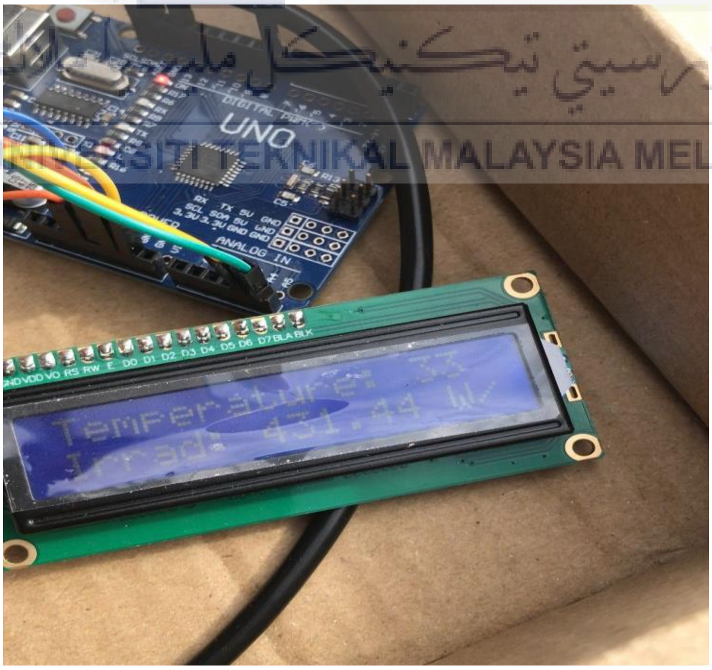

Figure 4.9 Temperature and irradiance values measured using the bh1750 and dht11

When the irradiance is high, the ambient temperature also affects it, resulting in a higher output current value due to the high irradiance. By using a multimeter, current and voltage can be measured. So, from the experiment that has been done for six days, this was proven when the irradiance is higher the output current will be increased. The solar panel is connected to the solar charge controller, the Arduino were connected to the solar charge controller to get a supply then from an Arduino it has bh1750 to measured irradiance and dht11 to measured surrounding temperature with i2c lcd to show the measured value, which is then from solar charge controller again connected to the battery. It is then connected to a 100 W inverter, which converts DC to AC for the use of AC equipment. It is then connected directly to the DB board, which contains a main switch, RCCB, and MCB. The main switch is used to turn the electrical supply on and off and to protect all fuses and wires within it. The RCCB detects and prevents electric leakage, ensuring protection against electric shocks caused by indirect contact. The MCB is used to protect installations or appliances from continuous overload and short-circuit damage. When the experiment has been done, the battery can last for 13 hours and 40 minutes to power the load. The load that has been used is bulb 5W, fan 20W, and charger 5W, but when the capacity of the load is added the endurance of the battery will decrease due to the wattage of the load.

4.6 Summary

This chapter summarizes the experimental data collection and the analysis performed to determine the perfomance of the portable solar generator performance. The proposed standalone PV solar system is targeted to be conducted on a bright sunny day so that the PV solar panels can produce maximum output power and charge the battery more quickly. The experiment demonstrates that the proposed system sizing is unsuitable to be tested during an overcast day. Throughout the rainy season, the sunlight during the day is inadequate to fully charge the battery bank to support the load when sunlight is unavailable. This project's main objective is to determine the suitability of the solar panel, charge controller, battery, and sensor for this solar generator development. Overall, the proposed standalone PV solar system is fully designed as the proposed specifications of the PV solar panel, charge controller and battery bank are sufficient to power the system as desired. Nevertheless, the portable solar generator has been successfully operated but the durability of the battery can survive will depend on the load used when the solar panel cannot charge the battery.

CHAPTER 5

CONCLUSION

5.1 Conclusion

This chapter summarizes the development of a portable solar generator, utilizing a self-sufficient solar-powered Photovoltaic (PV) system. The project aims to assess the viability of standalone PV solar elements in independently powering the load that has been used in this project which is lamp, charger and fan. The system comprises two integral components: the PV solar system, which converts solar energy into electricity to power the portable solar generator and charge the battery bank during sunlight, and the system equipped with irradiance sensor or bh1750 which is to measure irradiance and dht11 to measure temperature. This intelligent system ensures continuous functionality by seamlessly transitioning to stored battery power when sunlight is unavailable. Ultimately, this project represents a portable product to produce electricity and unlimited power sources. Meanwhile, safety breaker has been added to protect all device in this system.this will prevent any device damage.

5.2 Project Objectives

The three main objectives of this project are briefly revisited and discussed as follows:

5.2.1 To analyze the existing Solar Generator

In Chapter 2 of this project report, a few existing portable solar generators have been analyzed by studying the related articles, journals, and other researchers' works. The study has been done to review other researchers' works, especially on how other similar projects were designed and operated. Based on the literature review, several elements have been compared to find the most suitable components for designing the portable solar generator powered by the standalone PV solar system. Thus, the first objective of this project has been achieved.

5.2.2 To develop a portable solar generator

The second objective has been achieved by developing a standalone PV solar generator and monitoring by using sensor and manually measured. The standalone PV solar generator flow have been constructed to ensure the systems work as desired. Besides, the PV solar generator elements have been selected by comparing the components' specifications in Chapter 2. In Chapter 3, the sizing of the solar panel, charge controller, and batteries also calculated based on the system power usage. The project's design is essential to ensure the prototype's development goes as planned. The standalone PV solar system has been successfully developed based on the suggested design. Thus, the second objective of this project has also been achieved.

5.2.3 To test and evaluate the model perfomance of the voltage, current, power of a portable solar generator for emergency and remote usage and irradiance from the sun while monitoring the surrounding temperature

In this project, the combination of hardware chosen to build the portable solar generator must be compatible with one another in order to develop a standalone system.

The suitable sizes of solar panels, batteries, charge controllers and inverter and breaker that needed have been determined through study and calculations. The solar panel must produce sufficient energy to meet the specifications of the portable solar generator, and the battery bank must have adequate energy storage capacity for the system to operate when the sun is unavailable. The calculation has been made to estimate the endurance of the battery and the testing has been done but the results are not required as theoretical. From the experiment that has been done, the data has been taken to know the performance of the solar panel for 6 day. The irradiance were measured by the bh1750 and the temperature has been measured by using dht11. Meanwhile, voltage and current were measured by using multimeter. So from the data taken, the irradiance were affect to the performance of the solar panel to get higher output but the temperature also play a role that will affected the PV solar. From the experiment, the solar panel can work efficiently although the temperature is high

5.3 Project Limitation

During the development of the project prototype and the collection of testing data, several limitations and challenges were encountered, which affected the experimental output data.

Since the project testing is done near the end of the year, during the rainy season in Malaysia, it is cloudy for several days and is affected by the radiation, and the peak sun hour in those days is also shorter. The proposed PV solar system sizing is targeted to be conducted during a sunny day as the peak sun hour, as stated in the sizing calculation, was 4 hours.

Therefore, implementing the proposed PV solar system during an overcast day is incompatible as the ability of the solar panel to convert more solar energy to electricity will diminish. The selection of 40 Ah sealed lead acid batteries as battery banks has caused the charging system to be more complex because it requires a long time to fully charge the batterybank and the solution to faster the charging is to increase the size of solar panel to make the charging time shorter.

5.4 Recommendation

This project is focused on studying the suitability of the components used to build and monitor the performance of portable solar generators. The sizing of the solar panel, charge controller, and battery bank is the most important element in ensuring that the portable solar generator can sufficiently power the load during daylight and overcast days.

A few elements have been analyzed, including the solar panel's performance, charge controller, and battery bank endurance. Therefore, a few improvements can be made to this project. The recommendations provided are as follows:

i. Increase the PV solar panel's size to convert more solar energy into electricity even on cloudy days.
ii. Increase the battery capacity to 100 Ah to extend the battery bank's capability to powerthe load longer.
iii. Make a larger prototype for hanging the panel, so easier to carry
iv. In the upcoming projects, it is better for the solar panel to have tracker, so that it will be easier find the irradiance by itself

5.5 Project Potential

Every invention must have its commercialization potential, a transformative process turning it into a viable product or service, elevating the project to a stage where companies or factories would find interest in the resulting product or system. In this project, two systems show substantial commercial potential: standalone PV solar systems and monitoring system. For the monitoring system dht11 and bh1750 has been used to monitor the performance of solar panel. This can significantly test the efficiency of solar panel when get full irradiance and the surrounding temperature. Using a standalone PV solar system will give some value added by making the device more sustainable and resilient. It will reduce the dependency to use conventional power sources and can operate in areas with limited access to electricity. A portable solar generator will attract people and organization who are environmentally concious

REFERENCES

[1] L. Gibson, E. N. Wilman, and W. F. Laurance, "How Green is 'Green' Energy?,"*Trends in Ecology and Evolution*, vol. 32, no. 12. Elsevier Ltd, pp. 922–935, Dec.01, 2017. doi: 10.1016/j.tree.2017.09.007.

[2] M. R. Islam, R. Saidur, N. A. Rahim, and K. H. Solangi, "Usage of solar energy andits status in Malaysia," 2010. [Online]. Available: http://ejum.fsktm.um.edu.my

[3] Ç. Allahverdi, *FT-2 Creating awareness regarding solar energy and its use withportable solar powered generator*. 2021. [Online]. Available: https://www.researchgate.net/publication/358166023

[4] T. Güney, "Renewable energy, non-renewable energy and sustainable development," *International Journal of Sustainable Development and WorldEcology*, vol. 26, no. 5, pp. 389–397, Jul. 2019, doi: 10.1080/13504509.2019.1595214.

[5] Z. A. Abdul Majid *et al.*, "Design and performance of 20 watts portable solar generator," in *IOP Conference Series: Materials Science and Engineering*, 2012.doi: 10.1088/1757-899X/36/1/012040.

[6] M. B. Edeghe and P. O. Babalola, "200 Watts Portable Solar Generator for aTypical Barbing Salon," in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Sep. 2018. doi: 10.1088/1757- 899X/413/1/012029.

[7] K. Sopian, M. Yusof, and H. J. Othman, "DATA BANK Estimates of monthlyaverage daily global solar radiation in Malaysia," 1992.

[8] L. Q. Soh and C. C. D. Tiew, "Building of a portable solar AC & DC power supply," in *Proceedings - International Conference on Intelligent Systems, Modelling and Simulation, ISMS*, IEEE Computer Society, Sep. 2015, pp. 445–451.doi: 10.1109/ISMS.2014.82.

[9] M. S. Roslan, F. Adan, M. A. Mohammad, N. Norazman, S. Haizam, and Z. Haider,"Development of portable solar storage device," in *Journal of Physics: Conference Series*, Institute of Physics Publishing, Dec. 2019. doi: 10.1088/1742- 6596/1371/1/012002.

[10] S. T. Mohammad, H. H. Al-Kayiem, M. A. Aurybi, and A. K. Khlief, "Measurement of global and direct normal solar energy radiation in Seri Iskandarand comparison with other cities of Malaysia," *Case Studies in Thermal Engineering*, vol. 18, Apr. 2020, doi: 10.1016/j.csite.2020.100591.

[11] Fitria Hidayanti, "The_Effect_of_Monocrystalline_and_Polycr," *The Effect of Monocrystalline and Polycrystalline Material Structure on Solar Cell Perfomance*,vol. 8, no. No. 7, pp. 3420–3427, Jul. 2020.

[12] Noorul Islam University. Noorul Islam Centre for Higher Education. Department ofElectronics and Instrumentation Engineering, Institute of Electrical and ElectronicsEngineers. India Section. Circuits and Systems Society Chapter, Institute of Electrical and Electronics Engineers. India Section. Solid State Circuits Society Chapter, and Institute of Electrical and Electronics Engineers, *2015 International Conference on Control, Instrumentation, Communication and Computational Technologies : ICCICCT-2015 : 18 & 19 December 2015*.

[13] Institute of Electrical and Electronics Engineers. Indonesia Section and Institute ofElectrical and Electronics Engineers, *ICECOS 2018 conference : proceeding, International Conference on Electrical Engineering and Computer Science, October02-04, 2018.*

[14] M. Lokeshreddy, P. J. R. P. Kumar, S. A. M. Chandra, T. S. Babu, and N. Rajasekar, "Comparative study on charge controller techniques for solar PVsystem," in *Energy Procedia*, Elsevier Ltd, 2017, pp. 1070–1077. doi: 10.1016/j.egypro.2017.05.230.

[15] P. S. Acharya and P. S. Aithal, "A Comparative Study of MPPT and PWM Solar Charge Controllers and their Integrated System," in *Journal of Physics: ConferenceSeries*, IOP Publishing Ltd, Dec. 2020. doi: 10.1088/1742-6596/1712/1/012023.

[16] T. Majaw, R. Deka, S. Roy, and B. Goswami, "Solar Charge Controllers using MPPT and PWM: A Review," *ADBU Journal of Electrical and Electronics Engineering (AJEEE)*, vol. 2, 2018, [Online]. Available: www.tinyurl.com/ajeee-adbu

[17] C. A. Osaretin, "Design and implementation of a solar charge controller with variable output". Distributed Generation View project Application of RenewableEnergy to Oil and Gas facilities View project," 2016. [Online]. Available: https://www.researchgate.net/publication/303683238

[18] S. Chowdhury, M. Jakaria Rahimi, M. Riazul Hamid, J. Rahimi, and T. Moniruzzaman Sunny, "Design and Development of a Maximum Power Point Tracking (MPPT) charge controller for Photo-Voltaic (PV) power generation systemCharacterization and Modelling of Pt Killed P-N Rectifiers for Temperature Dependent Converter Applications View project Design and Development of a Maximum Power Point Tracking (MPPT) charge controller for Photo-Voltaic (PV) power generation system," no. 5, pp. 15–22, 2016, [Online]. Available: www.ajer.org

[19] M. S. Islam, "Thin Film Solar Charge Controller: A Research Paper for Commercialization of Thin Film Solar Cell," *Advances in Energy and Power*, vol. 3,no. 2, pp. 29–60, May 2015, doi: 10.13189/aep.2015.030203.

[20] H. Bahrami, S. Farhangi, H. Iman-Eini, and E. Adib, "A New Interleaved Coupled-Inductor Nonisolated Soft-Switching Bidirectional DC-DC Converter with High Voltage Gain Ratio," *IEEE Transactions on Industrial Electronics*, vol. 65, no. 7, pp. 5529–5538, Jul. 2018, doi: 10.1109/TIE.2017.2782221.

[21] M.A Laguado-Serrano, E.A Luna-Paipa, L.F Bustos-Marquez, and S.B.Sepulveda- Mora, "laguado serano," *Perfomance comparison between PWM and MPPT chargecontroller*, vol. 24, pp. 6–10, 2019.

[22] Windy Dankof, "windy dankof," *How to choose an inverter for an independentenergy system*, pp. 74–78, Apr. 2001.

[23] A. Ahmad and S. Maqbool, "Square Wave Inverters-A performance Comparisonwith Pure Sine wave Inverters," vol. 7, no. 1, [Online]. Available: https://www.theengineeringprojects.com/2016/10/introduction-

[24] M. V. Alminauskas, "Performance evaluation of lead acid batteries for use withsolar panels," 1993.

[25] Sena, B., Zaki, A., Rijal, H. B., Ardila-Rey, J. A., Yusoff, N. M., Yakub, F., Ridwan, M. K., & Muhammad-Sukki, F. (2021). Determinant Factors of Electricity Consumption for a Malaysian Household Based on a Field Survey. https://doi.org/10.3390/su

[26] Kasavan, S., Bin, S., Ali, S., & Siron, R. (2021). THE BEHAVIOUR OF HOUSEHOLDS TOWARDS ELECTRICITY CONSUMPTION: A CASE STUDY AT SEREMBAN. In Journal of the Malaysian Institute of Planners VOLUME (Vol. 19).

APPENDICES

Appendix A

```
#include <Wire.h>

#include <LiquidCrystal_I2C.h>

#define ANALOG_IN_PIN A1

#include <DHT.h>

#define DHTPIN 8                    //DHHTPIN 8

#define DHTTYPE DHT11                    //TIPE DHT

LiquidCrystal_I2C lcd(0x27, 16, 2);

DHT dht(DHTPIN, DHTTYPE);


#include <BH1750.h>

BH1750 lightMeter;

void setup()

{

  Serial.begin(9600);

  Wire.begin();

  lightMeter.begin();

  dht.begin();

  lcd.begin();

  lcd.backlight();

  lcd.clear();


}
```

```
void loop()
{

  int h = dht.readHumidity();          //FUNGSI DARI LIBRARY DHT VARIABLE H
  int t = dht.readTemperature();
  float lux = lightMeter.readLightLevel();
  float irr = (lux*0.0079);

  Serial.print("Humidity   : ");
  Serial.print(h);
  Serial.print(" %t");
  Serial.print("Temperature: ");
  Serial.print(t);
  Serial.println(" *C");
  lcd.setCursor(0,0);
  lcd.print("Temperature: ");
  lcd.print(t);
  lcd.println(" *C");



  Serial.print("irradiance: ");
  Serial.print(irr);
  Serial.println(" W/m2");
  lcd.setCursor(0,1);
```

```
  lcd.print("Irrad: ");
  lcd.print(irr);
  lcd.println(" W/m2");
  delay(1000);


  delay(300);
}
```

Appendix B

Table below shows the tasks or activities and duration to complete Bachelor Degree Project 1 and 2.

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	Work on the Software/Hardware	■																											
2	Project Title Conformation and Registeration		■																										
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	Submisiion Report to the Panel													■															
14	Presentation of BDP1														■														
15	Drafting Chapter 4: Analyse Data and Result												■																
16	Data Analyse 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	Finalizze the Report																										■	■	
22	Presentation of BDP2																												■