DESIGN AND FABRICATION OF BLUETOOTH SOLAR GRASS TRIMMER

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NUR ARISSA BINTI MOHD FADELAH

Thesis submitted in fulfilment of the requirements
for the award of the degree of
Bachelor of Engineering Technology in Manufacturing with honours

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of degree of Bachelor of Engineering Technology in Manufacturing.

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Date: JANUARY 2019

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ABSTRACT

Gas powered lawn mower are one of devices that contribute to the pollution especially air pollution. If using electrical powered, for sure it consumes large amount of energy for the working to move the cutting blades and the wheels. For the solution to nowadays problem as the mowers use fuel which could pollute the environment and produce lousy noise, this project is implemented with the objective to design and fabricate a Bluetooth Solar Grass Trimmer that easy to handle. A solar powered grass trimmer controlled by Bluetooth device with a systematic photovoltaic (PV) solar system was built in together with the trimmer as the source to reduce the manpower and usage of electricity. The process start by identify the problems occurred in the community. Then, proceed with the design constructed by using NX10 and choosing the right material for the trimmer. The materials were assembles to build the trimmer and were test at the field. After done the assembly part and the program are successfully installed, Bluetooth Solar Grass Trimmer is able to move forward and reverse by using dc geared motors. After that, the battery needs to be recharge again to power up the Arduino and motor driver. The grass trimmer also can be control by using the RC Bluetooth Controller. The application can be downloaded in the android phone. It is easier as it can be control from afar and safe for the children. The idea of invented Bluetooth Solar Grass Trimmer now can be used in home lawn area as it is portable and can be operates without human energy.

ABSTRAK

Pemotong rumput berkuasa gas adalah salah satu alat yang menyumbang kepada pencemaran terutama pencemaran udara. Sekiranya menggunakan kuasa elektrik, sudah pasti ia menggunakan sejumlah besar tenaga untuk bekerja untuk memindahkan bilah memotong dan roda. Untuk penyelesaian masalah saat ini kerana pemotong rumput menggunakan bahan bakar yang dapat mencemarkan alam sekitar dan menghasilkan bunyi bising, projek ini dilaksanakan dengan tujuan untuk mereka dan membina mesin rumput Bluetooth berkuasa solar yang mudah diatasi. Mesin rumput berkuasa solar dikawal oleh peranti Bluetooth dengan sistem solar photovoltaic (PV) sistematik dibina bersama-sama dengan pemotong sebagai sumber untuk mengurangkan tenaga manusia dan penggunaan elektrik. Proses ini bermula dengan mengenal pasti masalah yang berlaku di dalam masyarakat. Kemudian, proses diteruskan dengan reka bentuk yang dibina menggunakan NX10 dan memilih bahan yang sesuai untuk pemotong. Bahan-bahan itu dipasang untuk membina pemotong dan diuji di lapangan. Setelah selesai pemasangan unit dan program ini berjaya dipasang, mesin rumput Bluetooth berkuasa solar dapat bergerak maju ke hadapan dan ke belakang dengan menggunakan gear motor dc. Selepas itu, bateri perlu dicas semula untuk menghidupkan Arduino dan pemandu motor. Pemotong rumput juga boleh dikawal dengan menggunakan Alat Kawalan Bluetooth RC. Aplikasi boleh dimuat turun di telefon android. Ia lebih mudah kerana ia boleh mengawal dari jauh dan selamat untuk kanak-kanak. Idea untuk mencipta mesin rumput Bluetooth berkuasa solar kini boleh digunakan di kawasan rumput rumah kerana ia mudah alih dan boleh beroperasi tanpa tenaga manusia.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

cm	Centimeter
V	Voltage
m	Meter
mm	Millimeter
min	Minute
Ah	Ampere hour
Amp	Ampere
Rpm	Revolutions per minute
S	Second
W	Watt
Nm	Newton meter
Kg	Kilogram

LIST OF ABBREVIATION

SDP	Senior design project
PV	Photovoltaic
DC	Direct current
AC	Alternating current
RPM	Revolution per minute
EMF	Electromotive force
SLA	Sealed lead acid
AGM	Absorbent glass mat

1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

In the time where technology is merging with environmental awareness consumers are looking for ways to contribute to the environment by using devices with eco-friendly technology to decrease the pollution and protect the nature. Pollution is manmade and might be seen in our own daily lives, a lot of specifically in our own homes. Mostly, gas powered lawn mower are one of devices that contribute to the pollution especially air pollution. If using electrical powered, for sure it consumes large amount of energy for the working to move the cutting blades and the wheels. Nowadays, all the creation and new devices going under automation so our team tried to reduce the human effort for the trimming job.

The design objective is to come up with a grass trimmer that is portable, durable, easy to operate and maintain. It also aims to design a self-powered trimmer of electrical source which is a cordless electric grass trimmer. The heart of the machine is a battery-powered BLDC electric motor. The use of cable tie as blade makes the design unique such that less energy is needed for the motor to spin the blade. Thus, the machine is considered highly efficient as it uses no human effort and is readily adaptable to cutting conditions.

Our team would create solar grass trimmer which is efficient, less noisy and portable. The basic idea is that the grass trimmer is made with electric motor that runs from a 12-volt battery. This battery will be charged using solar panel of 30W on the grass cutter. This grass trimmer uses a solar based energy source which is easier to use, more advantageous comparing to other energy source. This grass trimmer is based on solar because this energy is a renewable energy source and it is easy to work. So this solar powered grass trimmer is build with the advantages as it is safe to use, efficient and environmentally friendly and for sure it saves on labor costs.

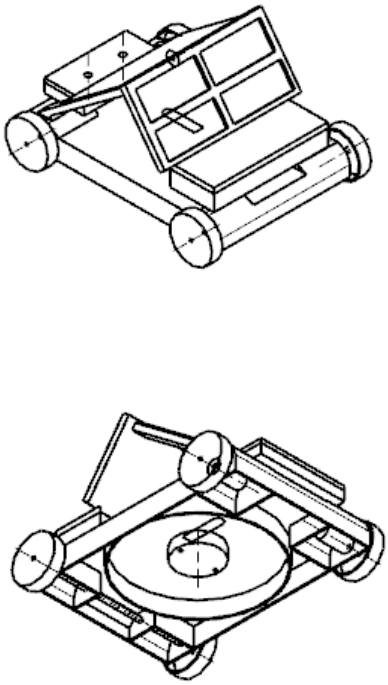

Figure 1.1 Design of Bluetooth Solar Grass Trimmer

1.2 PROBLEM STATEMENT

Nowadays, most of the activities which included human efforts are either replaced or automated by the use of machines or other kinds of equipment. The present technology commonly used for cutting the grass is by using the manually handle device which inconvenience due to heavy machines to carry and required human effort for proper handle. Solar grass trimmer is one the machines for public appliance provided to reduce human effort for mowing job. It uses blade to cut the grass, there are many grass cutting machine was built and introduced by industry, in this case to use and choosing the right power supply before implementing this project, there are various of battery that exist and we need to choose the most suitable type of source in order to complete the project based on the idea of portable and Bluetooth grass cutter. In order to build our own project, it still uses the same technology in term of power supply but need to decide the most suitable that can be used, it is the same in choosing the type of solar panel that will be used as this project is using a sustainable energy which is solar power. There are few problem statements for this project:

i. The usage of fuel grass cutter can caused pollution.
ii. It is noisy to use a grass cutter by a fuel usage.

In the time where technology is merging with environmental awareness, consumers are looking for ways to contribute for reducing the cause of pollution. By switching to modern technology from traditionally aspect, the implementation of solar trimmer devices is more environmental friendly compared to old cutting devices which can contributes to air pollution due to the internal combustion of engine. Therefore, solar grass trimmer devices are more preferable where the energy can be supplied from sunlight that absorbed by the solar panel to generate electricity.

Besides, the traditional lawn mower will consume engine oil in their fuel combustion to generate energy which generally creates byproducts and harmful pollutants. Thus, the energy efficiency can be achieved with the help of motor by using the solar energy. The grass trimmer devices is solar powered which the battery can be charge manually from main supply Hence, the energy consumption can be reduced and

carbon emission can be minimized. It also produces loud noisy sound when using fuel as the power source.

The problems with available grass cutter are

i. **Power consumption:** The available grass cutter are petrochemical powered or electrical powered which will consume large amount of energy source.
ii. **Human effort:** The mowing work always needs to get control with a worker for the proper mowing.
iii. **Time consumption:** For mowing the land in different patterns and design it takes larger time and human effort

Normal grass cutter usually consumes a lot of human energy over long distance and sometimes even short distance. The Bluetooth Solar Grass Trimmer is new-age that runs on batteries. It is equipped with movement controlled by the Bluetooth device that can cover the whole lawn home area with sufficient battery storage.

There are many types of grass cutter used by people at their homes. One of it is the manual grass cutter (refer figure 1.2) which needs human energy to make it works. Then, the technology improves by making a semi-automatic grass cutter which uses motor has to be operated manually by human (refer figure 1.3). Not to forget about the noise that the grass cutter produced which can disturb the neighbors. Other than that, there are many safety precautions that need to be improved either for the manual grass cutter or semi- automatic grass cutter as it is harmful to the people surrounding.

Figure 1.2 Manual grass cutter

Figure 1.3 Semi-automatic grass cutter

For the mentioned reasons above, we are now improving the grass cutter by making it a device which can operates by using Bluetooth device and less use of manpower. It basically reduces environmental pollution as it just uses the solar power to charge the batteries and operate without using fuel. It is environmentally friendly and also gives benefits to the consumers as it uses less human energy to operate (refer figure 1.4).

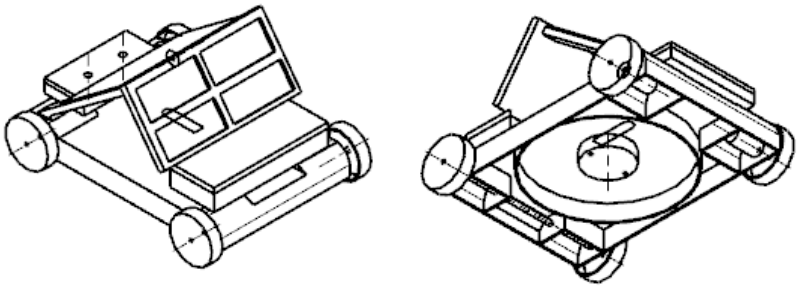

Figure 1.4 Bluetooth Solar Grass Trimmer

1.3 OBJECTIVES

i. To fabricate a bluetooth solar grass trimmer that easy to handle.
ii. To program a bluetooth solar grass trimmer which can driven by the motor driver and be able to communicate with the Bluetooth HC-05.
iii. To power the bluetooth solar grass trimmer with the solar panel system .

In this lawn grass trimmer uses a solar based energy source, which is easier to use, more advantageous comparing to other energy sources. Our lawn trimmer is based on solar because this energy is a renewable energy source and it is easy to work. So we made solar powered grass trimmer. In today's climate of growing energy needs and increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. One such alternative is solar energy. In this solar based lawn mower, the advantage of powering a lawn grass trimmer by solar is mainly ecological. We manufactured this lawn grass cutter because it is very easy method and many overcome produced from this type lawn cutter. The self-powered objective is to come up with a mower that is portable, durable, easy to operate and maintain. It also aims to design a self-powered grass cutter of electrical source. The supply of the project is a battery powered dc. It is also useful method for our lawn mower. The present technology commonly used for trimming the grass is by using the manually handle device. In this project we can control the trimming process of grass cutter by using Bluetooth. The device consists of feed spool with string which is operated with the help of the motor. The power supply for the motor is by using battery. The battery can be charge by using power supply and solar panel.

1.4 SCOPE OF STUDY

In this project, the main concern is on the design and the fabrication. The design is constructed by using the NX10 programme. The design dimension might be different from the real product. The design was build according to the criteria that suits the users demand. The Bluetooth Solar Grass trimmer design must be portable, in compact size, light weight and suitable for trimming the Cowgrass.

For the fabrication process, identify the ideal material and equipment that will be used for this Bluetooth Solar Grass Trimmer by selecting the material based on the size or dimension. Also, choose the material based on the quality and has affortable price. Then, plan a timeline to finish the fabrication process within four months. The fabrication process was conducted at the workshop under the co-supervisors observation.

CHAPTER 2

2.0 LITERATURE REVIEW

This chapter will discuss about concept and theory of this project. It reviews from different main parts and characteristic that is needed to make the solar grass trimmer. Hence, we would to highlight on four main parts of solar grass trimmer which includes body design and material, motor, battery and solar panel.

2.1. MATERIALS

2.1.1 Body Deck

Plastic is generally cheaper and so often found on budget, entry-level machines. Some of premium lawn mowers models such as Honda mowers use plastic for its deck. It is corrosion and weather resistant and comparatively light-weight. It also can even be terribly robust and a few impact resistant polymers can even rival metals for strength.

As for steel, it is a traditional and tough steel deck which is mainly found on petrol machines, their strength suiting the more rigorous demands of larger lawns and tougher mowing tasks. Some stamped steel decks can be quite thin but thicker steel is a prestige material that is durable and tends to be favored by high-end manufacturers. Steel decks area unit typically treated with powder paint that helps defend the deck and fight corrosion. Steel decks area unit usually impact resistant and can absorb impact injury fairly well.

For aluminium alloy decks, it is the arguably the premium choice material of the three. They have blessings of each the others, which include the strength and quality of steel and also the corrosion resistance of composite plastics. Aluminium alloy decks

where used on many top mowers and it is long-lasting and hard wearing. Aluminium, is a little more brittle than steel and does not have the same impact resistance as steel, but is usually a premium product and likely to be made from premium quality components.

2.1.2 Wheels

A standard-sized wheel could have problem rolling over rutty or uneven ground. Smaller wheels follow the curves a lot of closely than larger wheels. It could cause the mower deck to bottom out and scalp the lawn. Larger diameter wheels ar an improved match for ruts, grooves, depressions and rolling tract. The larger diameter is a lot of doubtless to span uneven ground, leading to a lower chance of damaging the field whereas mowing. Most in the markets nowadays sold this kind of mowers which use small diameter on front wheels and larger diameter on back wheels as shown in Figure 2.1 for the stability of the mowers.

Figure 2.1 Different diameter of grass mower wheels

2.1.3 Cutting Head

Cutting head used in grass trimmer nowadays were mostly use aluminium head. This item is made of made of solid aluminium, ensuring the durability. It can handle small vibration, durable and wear well. Aluminium head fit for most lawn mower, lawn trimmer and universal use. With practical and compact, it is a great accessory for grass brush cutter. For the lawn mower cutting head, nylon cable ties and traditional cutting blades were used. Nylon cable ties is flexible, affordable, lighter and easily replaceable but the line breaks easily if not used correctly , turns small rocks into projectiles and cannot handle brush or thicker weed stems. As for cutting blades, it is versatile use with

different blade attachments and powerful enough to cut brush and small trees. Although it is powerful but the cutting blade is cumbersome for large areas and can throw materials back at the user.

Figure 2.2 Aluminium cutting head

Figure 2.3 Cutting blades and nylon cable ties

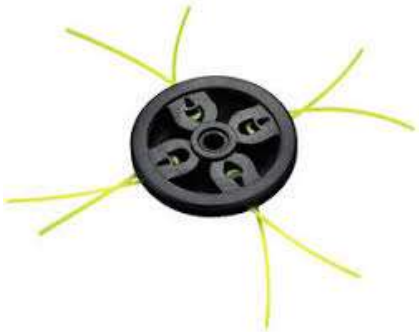

Figure 2.4 Plastic cutting head

2.2 MOTOR

For designing a grass trimmer, selecting a suitable electric motor is important criteria since the motor is the one that drives the generated torque to the cutting head to trim the grass and lead the grass trimmer to move the grass trimmer's wheels. Moreover, the size of the motor shall be suitable enough so that it will fit in perfectly inside the grass trimmer to move the cutting head and the wheels. Most of the electrical motors that ar obtainable within the markets ar costly and enormous in size. In addition, these motors ar used for serious duty field mowers since the cutting blades need an oversized quantity of power unit and move speed. A BLDC motor will be used since the cutting head will be using strings instead of cutting blades (Sivagurunathan, Sivagurunathan, & Jun Hao, 2017). If using string or cable ties trimmer, it only requires minimum rotational speed of 17000 RPM and estimated operating voltage is 15V-21V.

Figure 2.5 BLDC424 Brushless DC Motor

2.2.1 Motor Performance

There are a few parameters that can measure a motor's performance, including motor speed, RPM, and power. The theory and calculation of these parameters are discussed below.

2.2.2 Torque & Rpm

Torque is a measure of how much force acting on an object causes that object to rotate. A revolution per Minute (RPM) is a measure of the frequency of rotation around a fixed axis in one minute. It is used as a measure of rotational speed of a mechanical component. Higher RPM motors tend to generate less torque.

2.2.3 Motor Speed

In a motor, whenever there is relative motion between magnets and coils, a back electromotive force (EMF) is induced in the coils. Back EMF is proportional to the rotational speed of motor,

$$E = KV * \omega$$

Where E is back-emf, KV (Volts/RPM) is the back-emf constant and ω is the speed. In a basic circuit analysis, where resistor and back-emf is in series, we get,

$$V = R * I + E$$

$$= (R * I) + (KV * \omega)$$

$$\omega = \frac{V - R * I}{KV}$$

Where V is the DC supplied voltage, R (Ω) is resistor, I (A) is current. From the equation above, we can see that the speed of DC motor is equal to the applied voltage minus voltage drop due to resistance and current in the motor. As the current in the motor increases, the speed of the motor decreases. Current is proportional to torque, which also means that when torque of motor increases, the speed decreases.

2.2.4 Power

Power is the rate at which energy is generated or consumed. The more wattage the motor have, the more power on demand it has. Power used for an hour/Watt hour calculation is very important for building the trimmer because we can control the duration time and capacity needed to run it.

The formula that we use to calculate watt hour calculation is:

P = V x I

Where P = Power, V = Voltage, I = Current, 1HP= 0.7457kW

For example, the grass trimmer estimated motor rated with 3/4HP and 53A with full load running (Jeremy James 2014).Therefore, the voltage that we need is 10.55V. So, we can determine the suitable battery which is at 12V for supply voltage.

2.3 BATTERY

Firstly, sealed lead-acid (SLA) is the battery that constructed with vents or valves to automatically relieve pressure from gas buildup to avoid any discharged or overcharged. The sealed battery contains less amount of electrolyte as compared to the flooded type. Rather than submerging the plates in a liquid, the electrolyte is impregnated into moistened separators which enable the batteries to operate in any physical orientation without any leakage. The most significant advantages of sealed acid is the ability to combine oxygen and hydrogen which occurs at moderate pressure of 0.14 bar (2psi) to create water and prevent dry out throughout cycling("Types of Lithium-Ion Batteries – Battery University" 2017).

There are several types of sealed lead-acid with difference in technology which are absorbent glass mat (AGM) and gel cell. The AGM suspends the electrolyte in a specially design glass mat. This offers many benefits to steer acid systems, including faster charging and instant high load currents on demand. AGM works best as a mid-range battery with capacities of 30 to 100Ah which typically suitable use as starter batteries for electronic vehicles. In addition, the sealed lead acid battery is design with a low-over-voltage potential to prevent the battery from excess charging which lead to potential gas generating, venting and subsequent water depletion and dry out during charging.

In gel cell, the sulfuric acid in AGM battery is mixing with silica gel agent which converts liquid electrolyte into a semi-stiff paste to make the gel maintenance free. The gel separator is function as to move the heat whereas the absorbent glass mat of the AGM acts as insulator. This will improve the heat transfer to the outside of the battery and allows the battery to stay high performance range. However, gel cells required appropriate charge and float voltage because it too sensitive when overcharging occurs.

The common type of lithium-ion batteries that is used in most of the portable electric transportation in the market is Lithium-Ion Phosphate (LiFePO4) Battery. Lithium-ion uses a cathode as positive electrode and anode as negative electrode as well as electrolyte as conductor. The cathode is metal compound and therefore the anode consists of porous carbon. During discharge, the ions flow from the anode to the cathode through the electrolyte and separator which is charge in reverse direction and the ion flow from the cathode to the anode. Li-phosphate batteries is suitable for

electronic vehicles because it can maintain the topping charge which is can maintain at full charge level and prevent the sulfating on the batteries. Li-phosphate is additional tolerant to full charge conditions and is a smaller amount stressed than alternative lithium-ion systems if unbroken at high voltage for a chronic time. As a trade-off, its lower nominal voltage of three.2V/cell reduces the precise energy below that of cobalt-blended lithium-ion. In addition, Li-phosphate is suitable to replace the lead acid starter battery. For example, four cells of Li-phosphate connected in series can produce 12.80V has similar voltage to six 2V of lead acid cell connected in series("Types of Lithium-Ion Batteries – Battery University" 2017).

2.3.1 Battery Charging System

The lead acid battery uses the constant current constant voltage (CC/CV) charge method. A regulated current raises the terminal voltage until the upper charge voltage limit is reached, at which point the current drops due to saturation. The charge time is 12–16 hours and up to 36–48 hours for large stationary batteries. With higher charge currents and multi-stage charge methods, the charge time can be reduced to 8–10 hours. However, without full topping charge the lead acid battery is sluggish and cannot be charged as quickly as other battery systems. Lead acid batteries should be charged in three stages, which are constant-current charge, topping charge and float charge.

Stage 1: Constant-current charge

During the constant-current charge, the battery charges to about 70 percent in 5–8 hours which the remaining 30 percent is filled with the slower topping charge that lasts another 7–10 hours.

Stage 2: Topping charge

The topping charge continues at a lower charge current and provides saturation. If continually deprived, the battery will eventually lose the ability to accept a full charge and the performance will decrease due to sulfation.

Stage 3: Float charge

The float charge in the third stage maintains the battery at full charge.

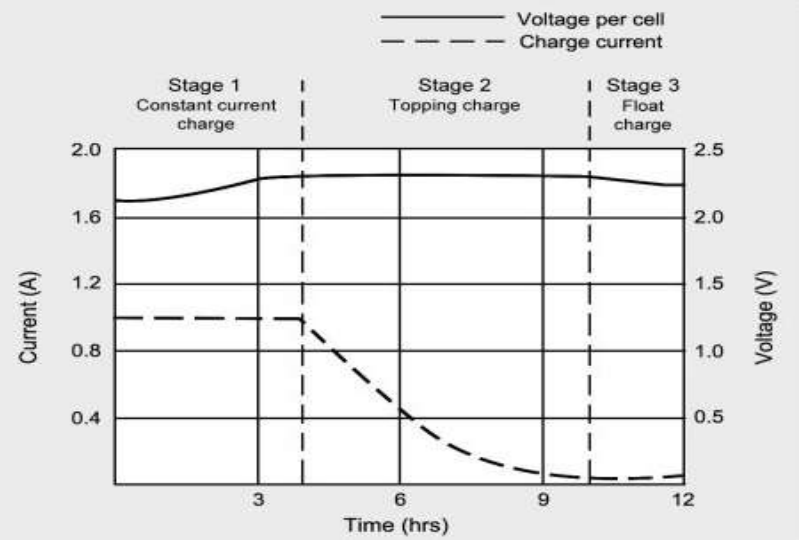

Figure 2.6 Charges stages for lead acid battery

2.4 MICROCONTROLLER

Software Program commonly defined as a set of instructions, modules or procedures that allow for a certain type of computer operation. Most of the solar grass trimmer is a program under Arduino whereas on microcontroller board which is open source electronics platform based on easy-to-use hardware and software. This system needs a controller that can be programmed to control all the movements on the circuit such as sensors, motor drivers, relay and etc. In fact, microcontrollers is an embedded application software that contains programmable input and output peripherals while microprocessor usually used in personal computers that consists of several chips.

A microcontroller is more economical to fix all the instructions compared to other devices that designed in separated memory, microcontroller board, the chips and their input/output pins. Several microcontrollers may use four-bit words and operates at clock rate frequencies as low as 4-kHz, for low power consumption. It has the ability to retain the functionality for such events such as timers, interrupts or even analog to digital converter.

The hardware integrated with one application as an embedded design is implemented using the 12C bus to interface different sensors and motor drivers to the ATMEL microcontroller chip (AVR Atmega32). There are many advantages in developing microcontroller based circuits and incorporating new sensor technology into

agricultural applications. Microcontrollers and solid-state sensors can be found in many consumer applications even in the factory.

There are a lot of microcontrollers that exists in this world such as 8051, PIC, ARM, and AVR. A very common use for the consumer nowadays is the Arduino Uno. Arduino Uno usually comes with a set of a board of Atmega328. In shorts, Arduino Uno consists of 14 digital input/output pins(in Figure 2.7) and combines with the application software such as Proteus and AVR. Moreover, to control and communicate with all the progress of the functions, the Arduino programming software(AVR) must be connected together with the hardware board that consists of our electrical circuit. Arduino software consists of some libraries that can provide extra functionality in sketches and will be uploaded by our own creativity.

Figure 2.7 Arduino Uno board.

2.5 SOLAR SYSTEM

Solar energy is the best alternative for producing electricity due to industrialization for various industrial applications and electrical gadgets. Solar energy emits less of pollution or greenhouse gasses effect. The variety of solar power technologies available run on a scale of efficiency, price, durability, and flexibility which depending upon the need of project. Solar photovoltaic (PV) systems are highly modular and making it's suitable for use on the demand side of electricity consumptions. PV solar technology generates power because substances like silicon generate an electrical current with the absorption of sunlight called photovoltaic effect. The solar photovoltaic effect can be observed in almost any junction material that has different electrical characteristics base on the material of their junction. The device used to utilize the photovoltaic effect is the solar cell.

In solar system, sunlight is directly absorbed by semi-conductor materials on the solar panel by hitting the photons. Semiconductor is the materials that have tendency to absorb sunlight and deliver a portion of the energy through the electron and hole which is absorbed by the photons to carries the electric current. A solar cell is simply semiconductor diodes which separates and collect the carries and conduct the generated electrical current conversely in a specified direction. The energy of light is directly converted into electricity through the photovoltaic effect. The photovoltaic effect is the creation of voltage or electric current in a material upon exposure to light. The figure below show the energy from the sunlight is directly absorbed into the solar cells through photovoltaic effect.

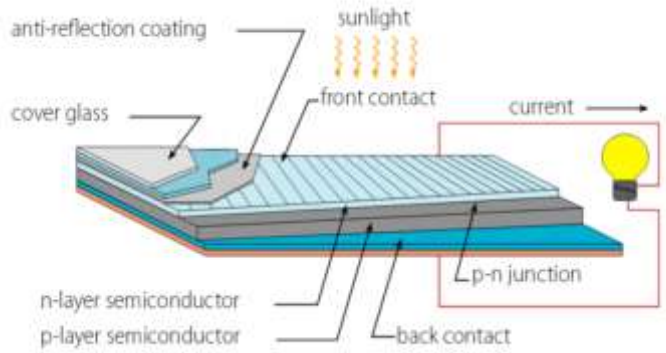

Figure 2.8 The solar cell structure

Solar cells consist of two layer which is p-type silicon and n-type silicon layer (figure). The sunlight is composed of photons or particles of solar energy that contain various amount of energy corresponding to the different wavelengths of the solar spectrum. The electrons presentin the valence band absorb energy which is in the excited state and jump into the conduction band and become free. These highly excited electrons are accelerated into a different material by a built-in potential. Thus, electromotive forces are produces by some of the light energy is converted into electric energy.

The operation of a solar cells is occurs when sunlight is falls on silicon metal cell by which the photon energy allows the electrons from the n-layer to move to the n-layer as show on Figure 2.5.2 below. The movement of electrons on the layer will create an electric potential difference on the semiconductor borders. When these borders are connected to a load by conductive wires, there will be a flow of electric current. The process will repeated when the electron is getting back to the p-layer. Generally, a

photovoltaic cell has low current and voltage level which approximately about 3A and 0.7V respectively ("Photovoltaic Panel Converts Sunlight into Electricity" 2010).

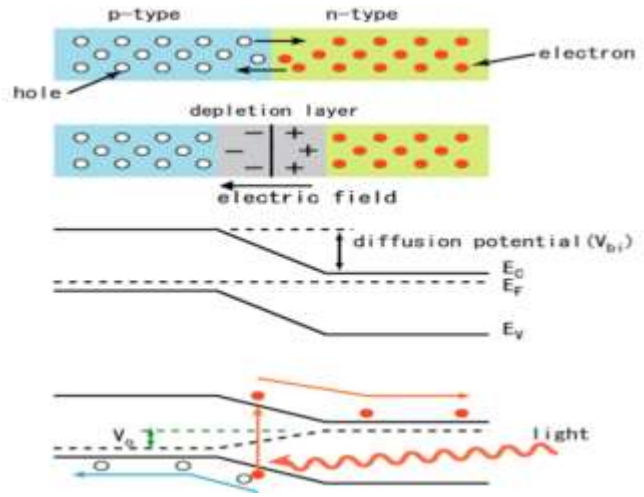

Figure 2.9 Operation of solar cells

2.6 SOLAR PANEL

For most applications, the types of solar PV module usually the best option use in industrial are polycrystalline silicon solar cells, monocrystalline silicon solar cells, and thin film solar cells. These technologies generally provide the right balance of price, efficiency, and reliability. Most solar panels range inefficiencies of 13% to 16%, though some high-end model modules can reach percentages as high as 20%("Solar Photovoltaic Cell Basics | Department of Energy" n.d.).

2.6.1 Mono-Crystalline Silicon Solar Cell

Solar cells made of monocrystalline silicon (mono-Si), also called single-crystalline silicon (single-crystal-Si), and are indicating with high purity of silicon. Monocrystalline solar panels have the highest efficiency rates since they are made out of the highest-grade silicon. The efficiency rates for monocrytsalline solar panels are typically between 15% - 20%. Generally, monocrystalline silicon solar PV is made up of single crystal which are cylindrical in shape. The shape of the panels is cut into the distinctive patterns that give them their recognizable appearance which is the sliced silicon cells expose the missing corners in the grid-like structure. Every each of the partition on the grid of the solar panel for monocrystalline design is rectangular shape with no rounded cutting edges that differences compare to other type of PV cells. The

crystal framework in a monocrystalline is even and producing a steady blue color with no grain marks as it can give the higher purity to achieve the higher efficiency. Monocrystalline solar panels tend to perform better than similarly rated polycrystalline at low-light intensity. This is due to space-efficient which requires least amount of space to yield the power outputs as its can produce up to four times amount of electricity. In terms of prices, the cost of producing monocrystalline is significantly higher compared to polycrystalline and thin film. Monocrystalline solar panels accounted for 38 percent of all modules produced in 2017, up from 25 percent in 2015("Monocrystalline Cells vs. Polycrystalline Cells | CivicSolar" n.d.).In addition, monocrystalline solar panels also live the longest. Most of the manufactures put in the range of 25 years warranty for monocrystalline solar panel.

2.6.2 Polycrystalline Silicon Solar Cell

The first solar panels based on polycrystalline silicon, which also known as poly-silicon (p-Si) and multi-crystalline silicon (mc-Si) that was introduced at the market in 1981. Unlike Monocrystalline-based solar panels, polycrystalline solar panels do not require the Czochralski process. Raw silicon is melted and poured into a square mold, which is cooled and cut into perfectly square wafers. Instead of using a single crystal of silicon, wafers are also formed through the melting process together with many fragments of silicon. The efficiency of the polycrystalline solar panel is typically 14%-16%. This is because of lower silicon purity due to many crystals in each cell that cause less freedom for electrons to move. As result, polycrystalline solar panels have lower efficiency ratings and not quite efficient compared to monocrystalline panels. However, polycrystalline solar panels tend to have slightly lower heat tolerance than monocrystalline solar panels. Polycrystalline solar panels will tend to have a higher temperature coefficient than solar modules which made with mono cells. This means that as heat increased output for this type of cell will fall less which will be losing it efficiency more quickly as the temperature is rise. Polycrystalline modules are easily distinguished by their blue cells that resemble a camouflage of molten silicon. In terms of prices, the cost of producing and selling of polycrystalline solar panels is much lower than monocrystalline. Adding to that, the estimated life of this solar panel is about 25 years same as monocrystalline.

2.6.3 Thin Film Silicon Solar Cell

Thin film solar panels are made of solar cells that have light absorbing layers about 350 times smaller than that of a standard silicon panel. The different types of thin-film solar cells can be categorized by which photovoltaic material that varies and combined onto this substrate:

- Amorphous silicon (a-Si)

  It is the non-crystalline form of silicon. The cell structure has a single sequence of p-i-n layers. When exposed to the sun, their power output is significantly decreased. The A-Si type thin film is manufactured in 6 steps. First, the glass substrate is coated with a TCO for transparent conductive oxide layer as front contact, followed by P1 laser scribing. Then a layer of a-Si is deposited followed by P2 laser scribing. Then a metal conductive layer is placed as back contact with the relative P3 laser scribing.

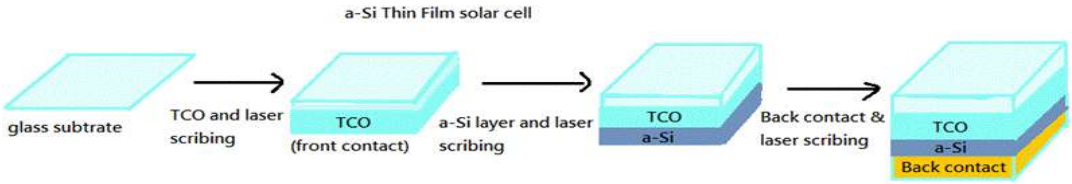

Figure 2.10 Composition of A-Si thin film

- Cadmium telluride (CdTe)

  It is formed from cadmium and tellurium. It is usually combined together with cadmium sulfide to form a p-n junction PV cell. The composition is similar to the a-Si solar cell with an additional Cds layer for buffer.

Figure 2.11 Composition of Cadmium telluride (CdTe) thin film

- Copper indium gallium selenide (CIS/CIGS)

  It is the semiconductor material composed of copper, indium, selenium, and/or gallium. In thin film technology, CIGS has the highest PV conversion efficiency.

CIGS/CIS has similar manufacturing process as a-Si thin films. However, as opposed to a-Si thin film, the glass substrate on CIGS/CIS is at the rear instead of the front. In addition, Cds is applied as a buffer layer.

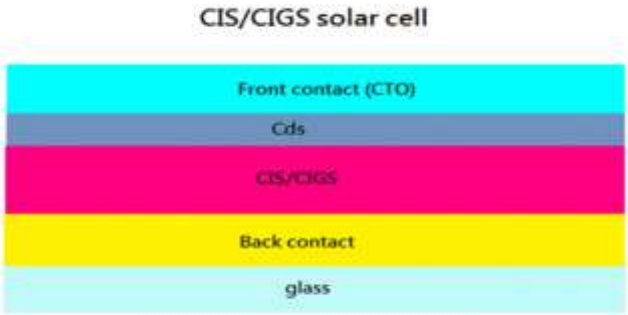

Figure 2.12 Composition of CIS/CIGS thin film

Thin-film solar cells has reached efficiencies between 7%-13% and production modulates operate at about 9% (Andrew Sendy, 2016) which is the lowest efficiency compared to types of silicon solar panels. In term of price and production, thin film solar panel is the lowest prices compared to polycrystalline and mono-crystalline solar panel. Since thin film solar panels are the cheapest panels to produce because of the low material costs for the thin film they are quickly becoming the more economically efficient panel types. Thin film solar panels have great advantages compared to other silicon solar panel because it is not affected by shade and high temperatures. The maintenance for thin film solar panels is not required periodically because of the photovoltaic materials used are able to absorb quite bit sunlight even if they are covered by shade. Additionally, because they are better able to resist high temperatures, these panels may be able to once and for all solve the problem of ambient heat in relation to solar panel output.

2.6.4 Solar Efficiency

Efficiency of a solar cell can be defined as the ratio of energy output from the solar cell to input energy from the sun. The efficiency is the parameter that used to compare the performance of one solar cell with other solar cell. Adding to that, the efficiency of a solar cell is depends on the spectrum, the intensity of the incident sunlight on the panel surface and the temperature of the solar cell. Thus, the conditions under which efficiency is measured must be carefully controlled in order to compare the performance of one device to another.

The efficiency of a solar cell is determined as the fraction of incident power which is converted to electricity and is defined as:

$$P_{max} = V_{oc} I_{sc} FF$$

$$\eta = \frac{v_{oc} I_{sc} FF}{p_{in}}$$

Where:

V_{oc} is the open-circuit voltage

I_{sc} is the short-circuit current

FF is the fill factor

η is the efficiency

The input power for efficiency calculations is 1 kW/m^2 or 100 mW/cm^2

2.7 BLUETOOTH HC-05.

Figure 2.13 BluetoothHC-05.

Bluetooth HC-05 is one of the types of serial communication. It designed for a transparent wireless serial connection communication setup. The port that comes from the module is fully qualified by the Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps modulation with 2.4GHz radio transceiver and baseband. The module works just only by AT COMMANDS and it cannot connect with other Bluetooth devices but can accept only the connections. The sensitivity for the module is -80 dBm while it can transmit the RF power up to +4 dBm. The input voltage for the module is around 3.3V to 5V and it connected to the Vin on the Arduino board for this trimmer.

Bluetooth HC-05 module consists of 6 pins which has their own functionality.

- **EN**: Short from 'ENABLE'. The module fails to connect with the Arduino and application software if it is pulled LOW while if it is connected to 3.3V, the module will enabled and the communication can runs smoothly.
- **Vcc**: The supply voltage for this module is 3.3V to 5V and it can simply connected to the Arduino board to make it ON.
- **GND**: Stands for the 'Ground' and connected to the pin GND on the Arduino board.
- **TXD and RXD**: TX short for transmit while RX is short for receive. These markings appear quite a bit in electronics to indicate the pins responsible for the serial communication. Both pins acts as an UART interface for communication.
- **STATE:** State acts as a status indicator. When it goes to HIGH, the LEDs will blinks with a 2s delay while when it goes to LOW, the LEDs will blinks for a long time and it indicates that the bluetooth is on paired.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION TO METHODOLOGY

This chapter explained in details on the procedures of the Bluetooth Solar Grass Trimmer. The methods used in this chapter are aimed to achieve the objectives of this project.

3.2 WHOLE PROCESS FOR BLUETOOTH SOLAR GRASS TRIMMER

Before starting the process, we planned the process flow well to make sure the Bluetooth solar grass trimmer were built on time with the right materials and using the right tools. The Figure 3.1 shows the overall process for fabrication and Figure 3.2 shows the project process flowchart.

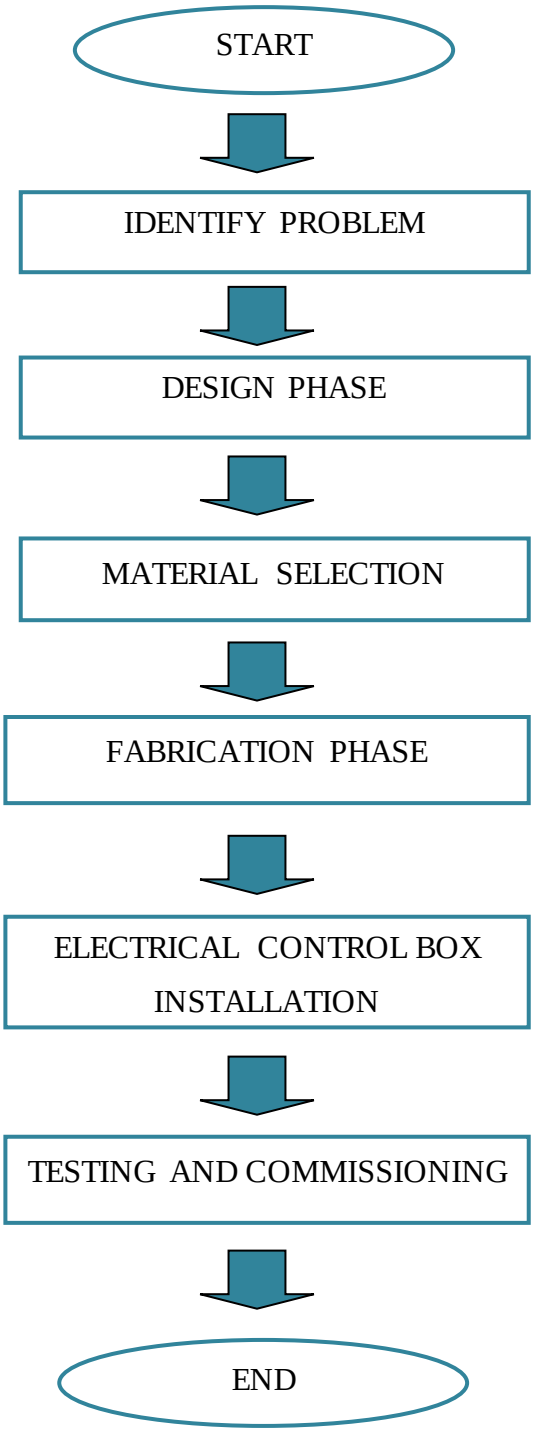

Figure 3.1 Overall processes for fabrication

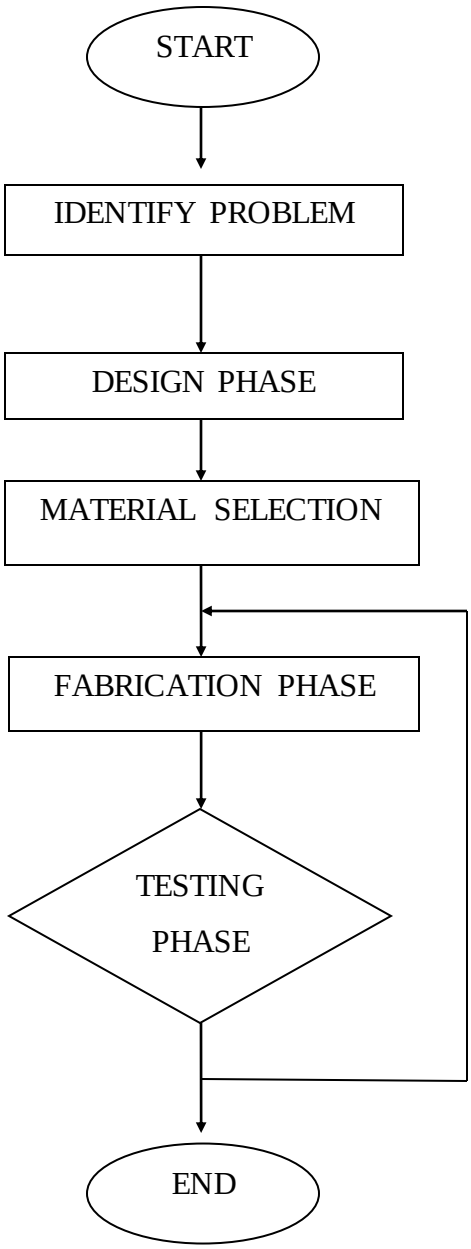

Figure 3.2 Project process flowchart

3.3 IDENTIFY PROBLEMS

A research has been carried out to identify the problems encountered for the grass trimmer. Based on the research study conducted, the problem faced when using other grass cutter and grass trimmer has been identified by studying the related articles and websites. The problem from the research stated that the available grass cutter are petrochemical powered or electrical powered which will consume large amount of energy source andinconvenience due to heavy machines to carry and required human effort for proper handle. Therefore, this project is implemented to overcome the problems identified and need to be customized for future research study.

3.4 DESIGN PHASE

Factors that affect the design of Bluetooth solar grass trimmer by considering every factor involve in this project. By considering the type of grass, the materials used to build this grass trimmer, speed of cutting head and the weight of component.

We expected to use this grass trimmer to trim the cow grass at place such as house compound or golf field. By using nylon cable ties with cutting speed around 8000 RPM will help to trim this cow grass well for about 2 to 3 inch with suitable height of cutting head. On the other hand, the materials used will help the grass trimmer to stabilize well during the trimmer process. With the well-size wheels, it could prevent the grass trimmer from stuck due to ruts and bumps or any obstacle at the trim compound and the trimmer's body will help to strength the grass trimmer as it can support the weight of component on it such as battery, Arduino sets and so on.

For the solar charger, we build it on the grass trimmer as it can carry the loads although it will take quiet lots of energy to move the grass trimmer as the solar panel is heavy. But, at the same time the solar panel will help to recharge the battery. This study therefore focused mainly to validate the new designed system of solar grass cutter with energy consuming.

In SDP 1 proposal before, the design that we propose was supposed to be as shown in Figure 3.3 and Figure 3.4where the solar panel will become a Solar Charger Port and not attach to the body of grass trimmer. The grass trimmer will go to the charger port when it needs to reload the battery. In SDP 2, we change the design as in Figure 3.5 as it is more suitable and preferred by our supervisor. It is easier for us to build it.

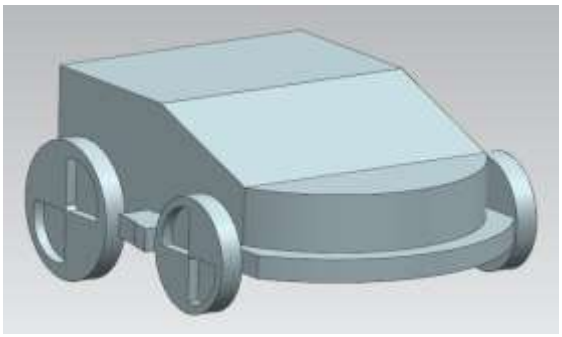

Figure 3.3 Bluetooth solar grass trimmer design in SDP 1

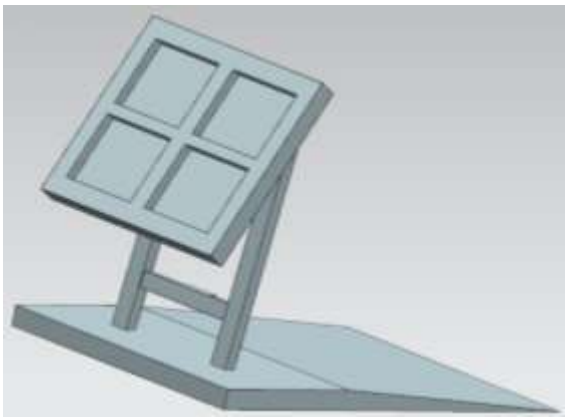

Figure 3.4 Solar Charger Port

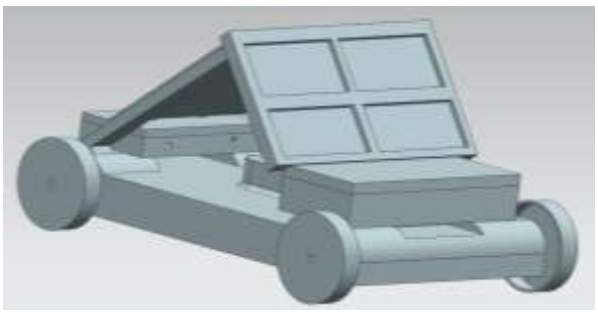

Figure 3.5 Latest design of Bluetooth solar grass trimmer

3.5 MATERIAL SELECTION

While designing the Bluetooth Solar Grass Trimmer, the materials needed are very important in order to make the project successful. If one of the materials is missing, then it can cause the project to not function as design plan. The materials needed are listed by part below:

3.5.1 Dc Geared Motor

12V 430RPM 1kgfcm 32mm Planetary DC Geared Motor with Encoder is used to move the tire forward and reverse. Lower speed will provide higher torque to drive the mechanism.

Figure 3.6 12V 430RPM Planetary DC Geared Motor with Encoder

3.5.2 Cutting Gear

550W and 30cm cutting swath is the perfect size for medium gardens. Manufacture with E-Drive technology; High torque gear system gets the job done faster through improved rate of cut.

Figure 3.7 550W Cutting gear

3.5.3 Black and Decker CM100-B1 City Mower

This 3Kg Black and Decker CM100-B1 City Mower are used as the trimmer body for easier and more consistent cutting over small turfed areas. It is lightweight and portable. Also, easy to carry and use on uneven ground and steep inclines.

Figure 3.8 Black and Decker CM100-B1 City Mower

3.5.4 Dual Line Automatic Feed Spool

This automatic feed spool allows grass hog to work without bumping. Then, factory-wound spools offer reliable and consistent operation with string refills are easy to install, lightweight, and durable.

Figure 3.9 Dual Line Automatic Feed Spool

3.5.5 Solar Panel

Polycrystalline solar panel is use to charge the battery which is the supply for the project as the power is completely used. A 30W solar panel was used in this project.

Figure 3.10 Solar panel

3.5.6 Aluminum Plate

Aluminum plate is a raw material with versatile properties of ensures high performance, durability and long life for its end products. It is a low weight material and has excellent corrosion resistance.

Figure 3.11 Aluminum plate

3.5.7 12V Lead Acid Battery

A rechargeable battery is the main source to operate the Arduino and the motor driver with the Bluetooth HC-05. It is also the source for moving the tires. The battery also store all the solar power absorbed from the solar panel.

Figure 3.12 12V Lead acid battery

3.5.8 Tires

5 inches rubber wheel is 5 inches in diameter and outer ring is made of rubber that provide great grip on most of surface. It was used to move the project as it is autonomous and need a movement.

Figure 3.13 Tires

3.5.9 Acrylic (Black)

Black Acrylic is use as the cover for the body of the Bluetooth solar grass trimmer.

Figure 3.14 Black acrylic

3.5.10 8 mm Metal Key Hubs

Metal key hub is a useful accessory of DC motor where it can convert the round output shaft of a DC motor to a flat surface that allowed to attach with a foreign part such as pully, wheel, sprocket. The 8mm metal key hub can fit with most of the 8mm diameter shaft's DC motor.

Figure 3.15 Metal key hubs

3.5.11 Electric Controller Box

An electric controller box is used in the project that provides protection and a safety barrier for electrical connections. These boxes are made from plastic.

Figure 3.16 Electric controller boxes

3.5.12 Colour Spray Paint

A black colour spray paint was used to colour the solar panel stand which is made from the aluminium plate.

Figure 3.17 Black colour spray paint

3.6FABRICATION PHASE

Fabrication is essentially the manipulation of raw materials such as metals like steel to make structures, machines and so on. It is basically the process by which metal structures are made by cutting, welding, machining, bending and assembling. In fact, fabrication is an integral part of the manufacturing process.This fabrication process start after the design and the material selection has been done.

For this project, the fabrication started with the body of the trimmer. The original trimmer's body was shown in Figure 3.18. We use the ready-made trimmer's body because it could take duration of times to build it.

Figure 3.18 Trimmer's original body

From this body, there are changes at the back tires where we need to exchange the plastic side with the aluminum plate to make sure the 12 gear for the movement of back tires fixed at its place. The aluminum plate was measured exactly as the real size of the side of trimmer's body. The aluminum plate was also perforated according to the size of the gear's coupling so that it able to accommodate well and rotate according to the speed. The aluminum plates were attached to the trimmer body by using the rivet as shown in Figure 3.19. The holes were made by using a drill.

Figure 3.19 Aluminum plate attached on the trimmer's body

Then, the gears were inserted into both left and right of the back tires. Gears The gears were attached in the body by using the screw to make sure the gears stick well inside the body as shown in Figure 3.20 below.

Figure 3.20 Gear inside the trimmer's body

Then, we proceed to the tires. The front tires use the tires given with the trimmer's body while the back tires were changed into 5-inch tires with the 8mm coupling hub. Coupling hub is composed of two shaft hubs, a metallic grid spring, and a split cover kit. Torque is transmitted between the two coupling shaft hubs through the metallic grid spring element.

Figure 3.215-inch tire with the 8mm coupling hub

Both tires and coupling were attached together. The tires and the gears were connected by the coupling hub. Then, it was attached to the gear as shown in the Figure 3.22 below.

Figure 3.22 Tires attached to the body

After the tires were attached, cutting blade motor was put into the place together with the factory-wound spools. Then, proceed with the electric box. Big size electric box were attached on the front of the trimmer's body which are fulfilled with two batteries and a 500W DC to AC inverter. One battery is connected directly to the inverter and the inverter supplied the AC current to the cutting blade motor. Another battery was connected to the electrical controller box to support the electrical component such as motor driver, Arduino and Bluetooth devices. Electrical controller box were attached behind of the cutting blade motor as shown in Figure 3.23 below.

Figure 3.23 Two electrical controller box were attached on the trimmer's body

Next is the solar panel. The solar panel will be attaching o the trimmer's body. Two stands were built to support the attachment of the solar panel. Both of the stands were made of aluminum plate. The stands were sprayed with the black colour air spray as shown Figure 3.24 below.

Figure 3.24 Two black colored stands

The stands were attached by riveting to the solar panel. Then, proceed to the cover for the grass trimmer. The cover was made from the black colour acrylic. The acrylic sheets were cut according to the dimension. Then, the acrylic sheets were attached to the trimmer's body to cover the wiring and the cutting blade motor as shown in Figure 3.25 below.

Figure 3.25 The back and sides black acrylic cover

All those solar panel, solar panel stands and the black acrylic cover were attached by screwing it to the trimmer's body. Lastly, the Bluetooth Solar Grass Trimmer was checked and is ready to do the testing.

3.7 TESTING AND COMMISSIONING

The Bluetooth Solar Grass Trimmer was tested at the grass area beside the Block T and also at the UMP football field. The implemented hardware system in the prototype of the trimmer has been tested and whenever there is any error, we will back to the above phase which is enhancement and optimization.

CHAPTER 4

RESULT AND DISCUSSION

4.1 OUTCOME OF FABRICATION PROCES

After the fabrication process along with the electrical component and wiring process, this project was managed to successfully develop a "Bluetooth Solar Grass Trimmer". All the electrical appliances can be controlled and monitored using Android app which is the Bluetooth Arduino RC Controller.

Figure 4.1 Isometric view of Bluetooth Solar Grass Trimmer

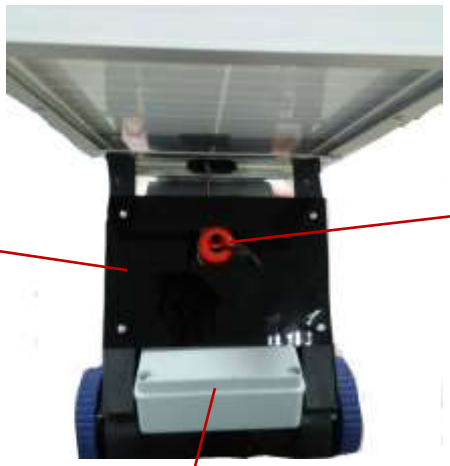

Figure 4.2 Rear view of Bluetooth Solar Grass Trimmer

Figure 4.3 Underneath view of Bluetooth Solar Grass Trimmer

4.2 APPLICATION CONTROL

The Bluetooth Solar Grass Trimmer can be control by using an application known as Arduino Bluetooth RC Car. The Bluetooth Controller can be paired from the smartphone to the trimmer. It provides full command to control the moving direction of the trimmer that makes it easily to send start, stop and park commands. This is some steps on how to connect Bluetooth HC-05 via mobile phones.

Firstly, connect the Bluetooth symbol in own user's phone. Then, it will ask for the password. The password for this Bluetooth HC-05 is '1234' or '0000' and it will pair each other. Continue connect (ON) the Bluetooth symbol.

Figure 4.4 Application software

Next, search for the application 'Arduino Bluetooth RC Car' in 'Play Store'. However, this application is not applicable for the iPhone users. If the iPhone users want to connect this application, they need to buy an Android phone or they cannot use the trimmer.

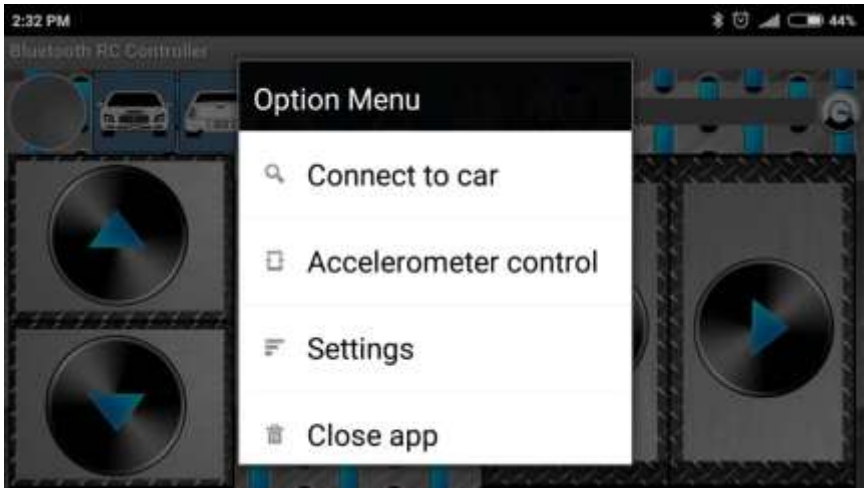

Figure 4.5 Setting menu

Proceed with the setting menu in the application. The Option Menu will be pop-up, and choose for the Connect to car in the first row and the user will find the device. For the information, user still need to connect with the 'HC-05' as in the Figure 4.6 to drive the trimmer or else user cannot control the trimmer or even move the trimmer and the blade. Finally, user can control the trimmer at the range of 10m.

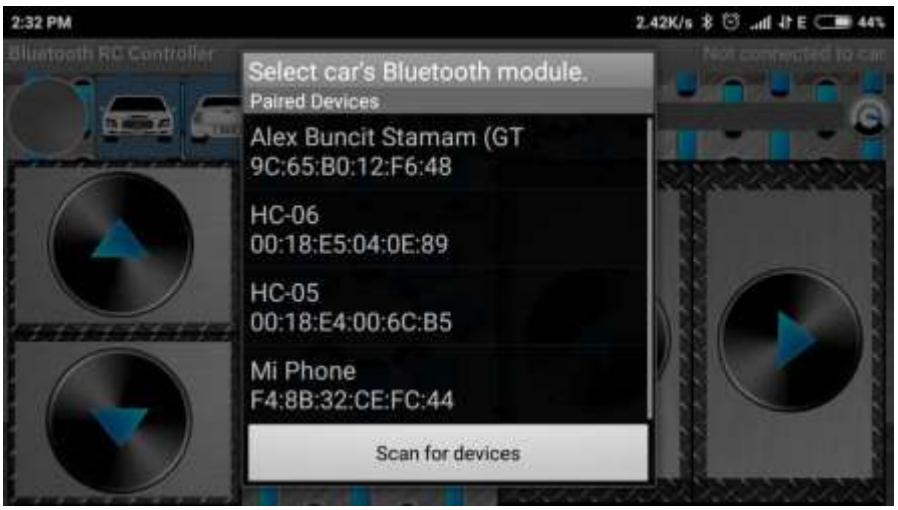

Figure 4.6 Scan for devices

4.3 PWM OVERCHARGE AND DISCHARGE PROTECTION

In a 12 V battery system, the voltage is varying between 11.90 volts and 14.4 volts. In this project, an experimental on analyzing the time taken for battery to fully charging by a 30W solar PV was conducted. The value of the current produces is varying depending on the solar irradiances. Overcharge may occurs when the battery is charging, while deep discharging may happen when load are connected into the system as the Bluetooth solar grass trimmer is running.

4.3.1 Overcharge Protection

The battery voltage is depends on the actual state of charge of the battery, charge current, discharge current, type and age of the battery. When a normal full loaded battery and no charging or discharging current is flowing than the battery voltage is about 12.4 volts to 12.7 volts. When charging current is start flowing, the voltages will jumped to a higher level value in a period of time. When the loads are switched on, it will causing the voltage to drops down to a lower level which in the range of 12.0V to 11.50V. Meanwhile, the PV module produces energy and current for battery charging which will cause the battery voltage to rise in a period of time until the battery voltage reaches at maximum level. Then, the charge controller will switch off the charging current or reduced it by pulse width modulation (PWM) to avoid from overcharging occurs.

4.3.2 Deep discharge Protection

When we deep discharge the battery repeatedly, loss of capacity and shortened of battery life will eventually occur. To protect battery from deep discharge, the PWM charge controllers will disconnect the system loads once the battery reaches a low voltage or low state of charge condition. If the voltage of the system falls below 11.5 V for a period of a few second, then the charge controller will be switched off. All the loads which are connected in the system to the controller are switched off. In addition, if the battery voltage increases above 11.5V, the charge controller will be switched on the loads to operate as well as for charging the battery.

4.4 BATTERY STATE OF CHARGE

The Figure 4.7 below shows the relationship between the states of charge against battery voltage during the constant charging current with no load condition.

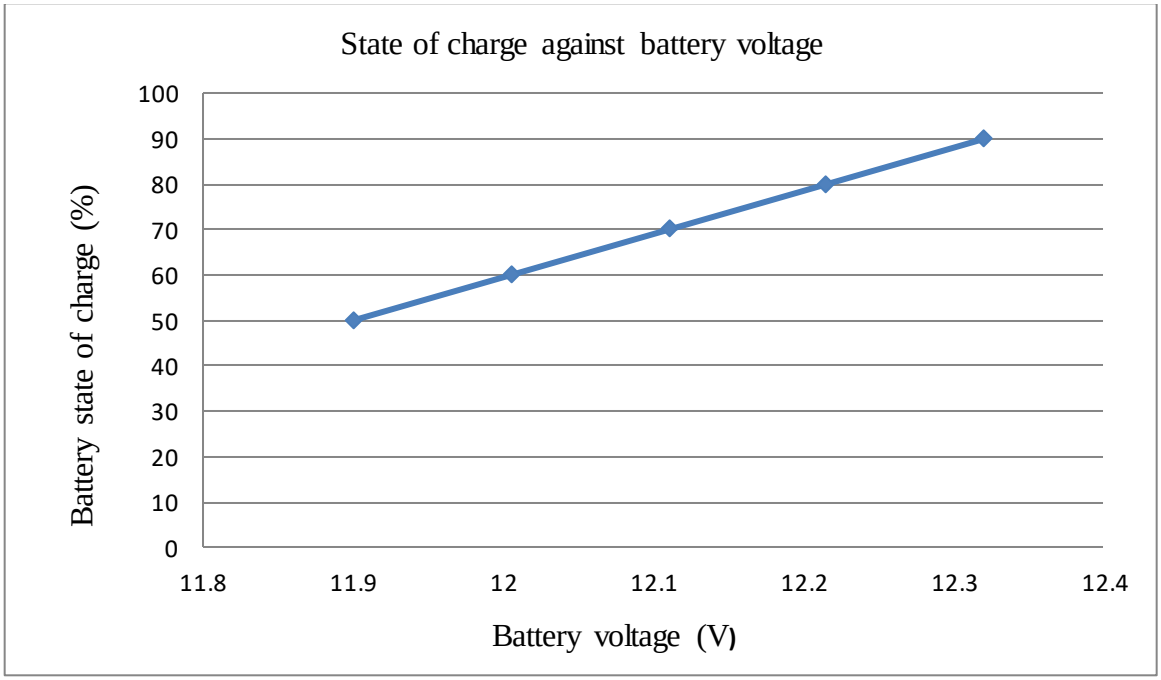

Figure 4.7: State of charge against battery voltage

From the result obtained in Appendix B1, the graph of state of charge against battery voltage was set up. It indicates that the battery voltage is directly proportional to the state of charge(Murnane, n.d.). It can be seen that, during the charging time interval, the battery voltage is increase due to the battery state of charge increase. If longer the charging time interval, the battery voltage will increase until it reached a threshold as well as the state of charge that can be achieved until hundred percent of state of charge (Gabler et al, 1995). Additionally, if the battery voltage is below the minimum level which at 11.90V, indicating the battery is in discharging condition. However, the batter voltage is more significantly affected by the battery current due to the battery's electrochemical kinetics, irradiances and temperature (Armstrong et al, 2008).

4.5 PV MODULE ANALYSIS

Firstly, all the system parameter such as output PV current, voltage and irradiances was initialized in Appendix C1. As to analyze the power input produces from the 30Watt solar panel, the graph of power input against voltage with varying in irradiance was set up.

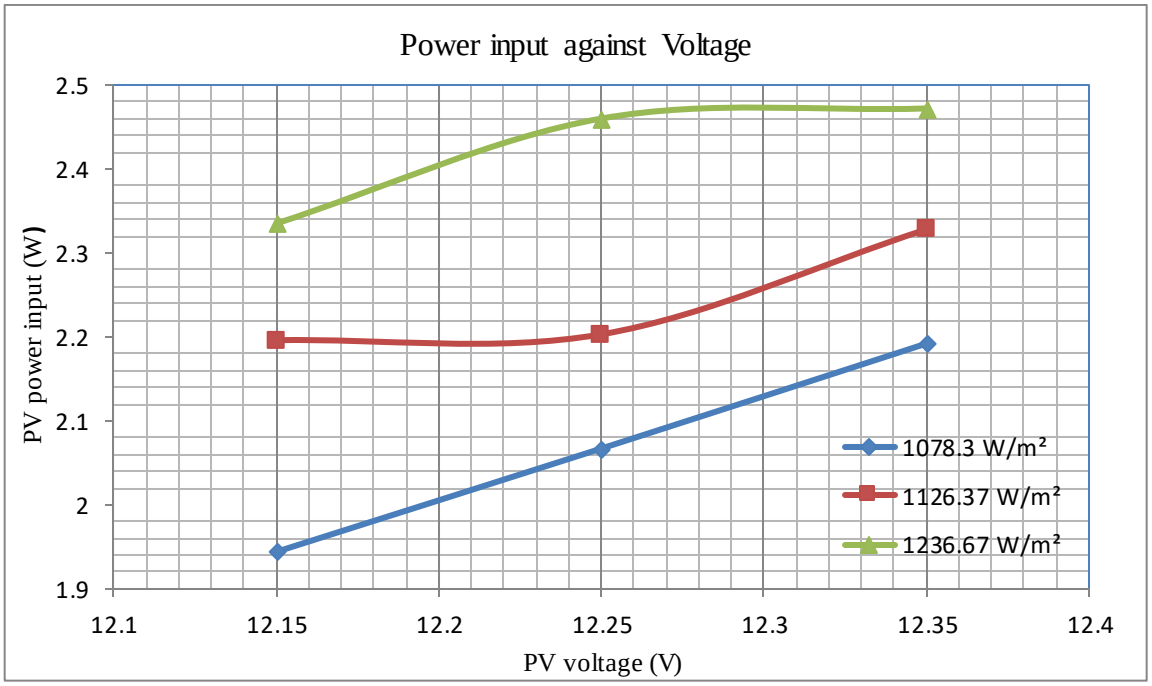

Figure 4.8 Power input against Voltage

From the result obtained, the voltage and current produces by the PV module at differences average of irradiances. The power input is obtained from the calculation by using current and voltage value produces by the PV module for a period of time. In an open circuit voltage, when the irradiances is constant for a 10 minutes period, the current produces will constant but the voltage produces by the PV is increase. The current produces through the PV module was affected by the solar irradiances (Abu Eldahab et al, 2016). It can be seen that, when the solar irradiance is higher, the current produces is increase resulting the higher power input produces (Florida Solar Energy Center, n.d.).

4.6 BATTERY CHARGING PROFILE AT CONSTANT AVERAGE IRRADIANCE

Figure 4.9 shows the battery charging profile under load and no load condition. The result of the testing was recorded in Appendix A1 and A2.The irradiances was measured for average of three reading during the 1 hour period charging time, while the battery voltages were measured at every 10 minutes for both under load and no load condition.

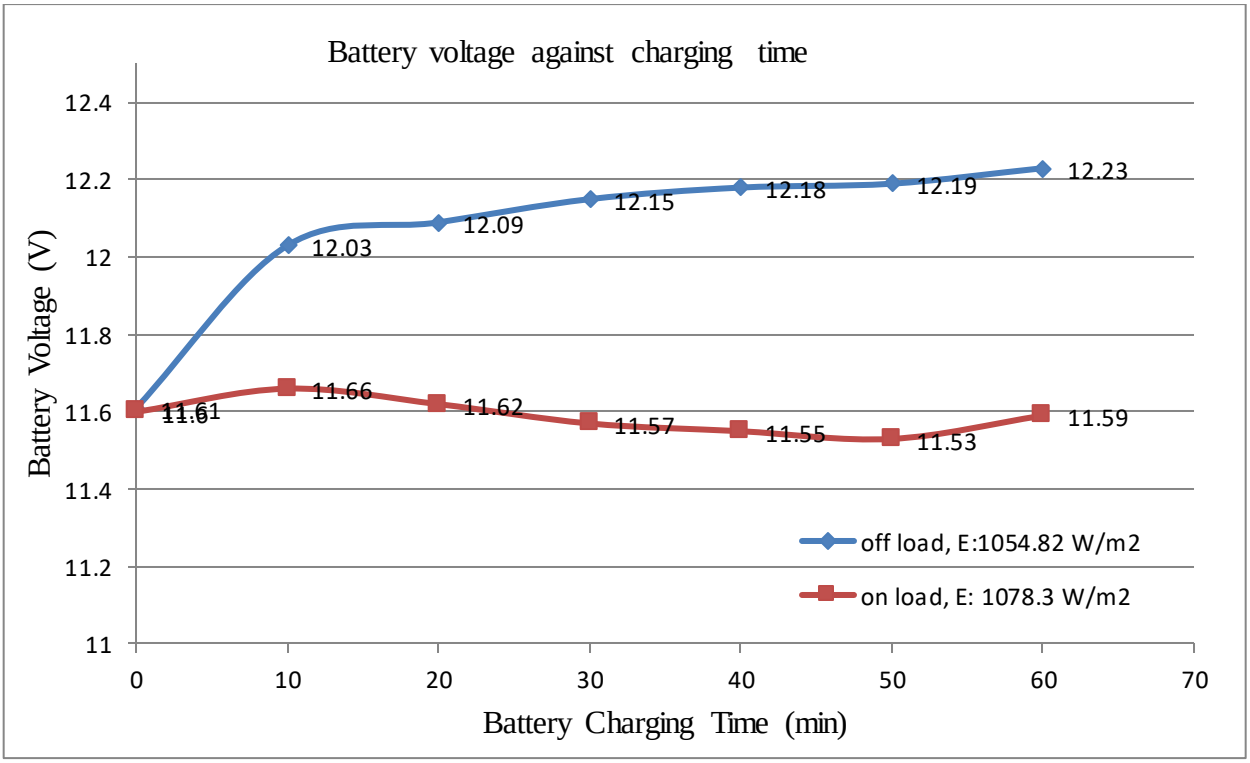

Figure 4.9 Battery charging profile

It is seen that, during the bulk charge phase, for no load charging condition, the PV source is directly connected to the battery with addition of PWM charge controller until the battery voltage rise to 12.23V for one hour period under 1054.82W/m^2 (Dunlop, n.d.). During the charging time under no load condition, the actual charging current is allowed to be equal to or less than maximum current which is the battery-charging current depends on the PV power production and varies according to the irradiance conditions (Chowdhury et al., 2008). The flow of current produces from the PV will cause the battery voltage to rise (Perez, 1993). However, during the time interval of 20 until 50 minutes charging time of under load condition, the voltage value

was drop steadily depending on the charge rate which varies due to irradiances and also the current from loads consumption. As the battery is to be discharged, the discharging current causes the battery's voltage to drop. If the battery voltage below the LVD set point, the load will disconnect through PWM charge controller to prevent from over discharge.

4.7 ETHICAL CONSIDERATIONS

Before the fabrication process start in the workshop, the safety precaution must be practice to avoid any injuries. In early semester before, all the SDP 2 students must attend the workshop training to learn on how to handle the machines and learn the safety precautions. Rules and regulation while working in machine room need to be obeying for our own safety. Safety measure needs to be taken into account at our workplace such as wearing safety boots, jackets, goggle and mask all the time when handling tools and machine. The jacket will protect us from the chips, dust or any fire sparks that produced during the cutting of the metal sheet. The chips produce during cutting process is quite sharp and hot which could cause injuries. The safety boots protect our feet from getting hit by heavy materials which could cause fracture and bleeding. Every different type of operations on machine likes milling machine and turning machining including drilling, cutting using saw must be conducted follow by the correct procedure and tools to avoid accident happen in the workshop. Wearing watch or bracelet is prohibited at the workshop to prevent from draw into the rotating machines and accidents occur. Wearing gloves is also compulsory during the fabrication process to protect from any harm such as sparks and chips. Also, push the emergency red button at every big machine to prevent from any sudden startup or movement from the machine. The floor must always dry to avoid slippery and the table must be clean repeatedly after used.

4.8 TIME MANAGEMENT

4.8.1 Gantt Chart

Activities	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Preparation of the letter for material purchasing														
Build up the design														
Create a coding														
Test and modify the design														
Robot successfully built														
Analysis the data/ Tabulation of data														
Writing a report														
Final thesis report submission														

Table 4.1 Project Timeline Senior Project Design 2

4.8.2 MILESTONES for SDP2

Week 1 : Prepare the letter for material purchasing.

Week 2 -8 : Build up the body design for the "Bluetooth Solar Grass Trimmer". Create a suitable coding to control the movements of the robot and run the test on it.

Week 8-11 : Run the test on the robot simultaneously until get the finals result.

Week 9-11 : Analyze the data obtained by using theoretical analysis method.

Week 10-13 : Writing a report from the collected data.

Week 13-14 : Prepare and submit the final thesis of report.

4.9 COST ANALYSIS

Below are the tables of all items listing including with quantity, cost per unit and total cost of all parts.

No	Materials	Costs (RM)	Quantities (units)	Total Cost (RM)
1	Arduino Compatible Atmel DIP ATmega328P UNO R3 + USB B type cable	31.10	1	31.10
2	MD30C motor driver	125.00	2	250.00
3	5V 1 Channel Relay	5.00	1	5.00
4	Toggle Switch	2.00	1	2.00
5	Bluetooth Serial Transceiver HC-05	15.90	1	15.90
6	12V 7.2Ah Battery	42.00	2	84.00
7	Controller Box (medium)	9.50	1	9.50
8	Controller Box (big)	13.50	1	13.50
9	Solar Charge Controller	90.00	1	90.00
10	PCB stands	0.80	8	6.40
11	Voltage Regulator +24V	1.00	1	1.00
12	OPS 20A PVC Connector	2.00	1	2.00
13	30W Solar Panel	145.00	1	145.00
14	Black & Decker Body Trimmer	300.00	1	300.00
15	Acrylic (Black)	30.00	1	30.00
16	Tire + Coupling Hub	80.00	2	160.00
	TOTAL (RM)			**1145.40**

Table 4.2 Budget and cost analysis

The faculty provided RM500.00 per person as budget to buy all the materials and equipments to build the product. Our group consists of three students from BTM, BTE and BTV. The total budget of our group is RM1500.00. From this cost analysis, our group has spent for about RM1145.40 during this SDP 2 to buy materials and equipment for the product and the remaining money was RM354.60.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As a conclusion, the objectives are achieved. We are able to develop a solar power to battery and also able to construct a system of solar energy that convert to electricity as one of the power source. Besides that, it also produced less noise as it is a zero fuel usage trimmer. The cost is also less than the previous grass cutter. It is also can reduce the affect of pollution as it uses solar panel as a replacement for fuel usage. Lastly, less human effort are used as we need to only control the trimmer using the Android devices and can reduce time delay from human works.

After done the assembly part and the program are successfully installed, Bluetooth Solar Grass Trimmer is able to move forward and reverse by using dc geared motors. After that, the battery needs to be recharge again to power up the Arduino and motor driver back and starts the motor connected to it. The grass trimmer also can be control by using the RC Bluetooth Controller. The application can be downloaded in the android phone. It is easier as it can be control from afar and safe for the children. The idea of invented Bluetooth Solar Grass Trimmer now can be used in home lawn area as it is portable and can be operates without human energy.

5.2 RECOMMENDATION

End of this development, after testing the Bluetooth Solar Grass Trimmer, there are some improvement required to achieve the convenient for the user. The improvements are stated as follow:

1. Consume large battery capacity from 12V to 24V to increase the life span of the trimmer and increase the efficiency of cutting blade.
2. From Bluetooth to automated by using the sensor where the trimmer becomes fully automated.
3. Use DC Motor as the cutting blade motor for more efficiency.
4. Use bigger size for the wheels to get better grip and movement.
5. Build an adjustable height grass trimmer so that it can be use to trim any type and height of grass.
6. Use an application that is also available to the IPhone users as this trimmer only can be controlled by using Android devices.

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APPENDIX A

BATTERY CHARGING DATA AND CALCULATION

A1 Battery charging without load

$$\Delta\text{Irradiance } W/m^2: \frac{(1037.68+1026.37+1100.41)W/m^2}{3}$$

$$= 1054.82\ W/m^2$$

Table A1: Battery charging without load

ΔIrradiance W/m²	Time (min)	Voltage (Battery)
	10	11.61
	20	12.03
	30	12.09
1054.82	40	12.15
	50	12.18
	60	12.19
	70	12.23

A2 Battery charging with load

$$\Delta\text{Irradiance } W/m^2: \frac{(1113.0+1125.0+996.9)\,W/m^2}{3}$$

$$= 1078.3\ W/m^2$$

Table A2: Battery charging with load

ΔIrradiance W/m²	**Time (min)**	**Voltage (Battery)**
	10	11.60
	20	11.66
	30	11.62
1078.3	40	11.57
	50	11.55
	60	11.53
	70	11.59

APPENDIX B

BATTERY STATE OF CHARGE CALCULATION

B1 Calculation of battery state of charge by using interpolation method:

Assumption:

At initial 50% of SOC: 11.90V

At final 90% of SOC: 12.32V

Interpolation,

At 50% of battery SOC:

$$\frac{(12.32 - 11.90)V}{4} = 0.105V$$

Thus,

60% SOC: 11.90V + 0.105V = 12.005 V

70% SOC: 12.005V + 0.105V = 12.11V

80% SOC: 12.11V + 0.105V = 12.215V

90% SOC: 12.215V + 0.105 = 12.32V

Table B1: Battery voltage and state of charge

Battery Voltage (V)	Battery SOC (%)
11.90	50
12.005	60
12.11	70
12.215	80
12.32	90

APPENDIX C

PV MODULE DATA ANALYSIS

C1 LABORATORY ANALYSIS FOR PV MODULE

Table C1: Data analysis for PV module

Irradiance (W/m^2)	Time (min)	Current (A)	Voltage (V)	Power (W)
1078.3 W/m^2	10	0.16	12.15	1.944
	20	0.17	12.16	2.067
	30	0.18	12.18	2.192
1126.4 W/m^2	10	0.18	12.20	2.196
	20	0.18	12.24	2.203
	30	0.19	12.25	2.328
1236.67 W/m^2	10	0.19	12.29	2.335
	20	0.20	12.30	2.214
	30	0.20	12.36	2.225