Development of PV and TEG Integrated Charging System for Rechargeable Lithium Ion Battery for Hybrid Car

WAN AKMAL SYAHIRAN BIN WAN AHMAD

A report submitted in fulfillment of the requirement for the degree of Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

I hereby declare that I have read through this report entitle “Development of PV and TEG Integrated Charging System for Rechargeable Lithium Ion Battery for Hybrid Car” and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)

Signature : .....

Supervisor’s Name : En. ZUL HASRIZAL BIN BOHARI

Date : 29/05/2015

I declare that this report entitle “Development of PV and TEG Integrated Charging System for Rechargeable Lithium Ion Battery for Hybrid Car” is the result of my own research excepts as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : WAN AKMAL SYAHIRAN BIN WAN AHMAD

Date : 29/05/2015

ACKNOWLEDGEMENT

Assalamualaikum warahmatullahi taala wabarakatuh,

First and foremost, I wish to express my deep gratitude to Allah, The Al-Mighty for giving me enough time and ability to finish this Final Year Project II. I would like to express my thanks and appreciations to my supervisor, En Zul Hasrizal Bin Bohari, for his guidance, advice, co-operation, encouragement, support and useful ideas during this Final Year Project. Most importantly I extend my gratitude to my senior Zulfikri Zaki, friends, foreman, technicians and all staff FKE UTeM. This units gives me valuable guidance, assistance and support throughout this Final Year Project. Lastly, especially indebted to my parents for their support, patience and assurance during my pursuit for higher studies. They have encouraged me throughout my education and foremost during this Final Year Project. Their endless support throughout my studies, for giving me meaningful advice and support me in term of financial support. Being a student handling a project is not easy as people thought. Without parental guidance, support and encouragement, I would not believe that I can have my project completed as it has present here.

ABSTRACT

Sales of hybrid and electric cars are rapidly gaining in the market nowadays. The factors these two vehicles production actually caused by two main reasons that are to reduce fuel consumption and reduce greenhouse gases emission. Generally the rate of air pollution can be reduced by using an alternative way which is generating renewable energy from clean energy sources. Hybrid and electric vehicles have within them an electrical source system such as braking system and rotation of tire that will produce electricity for charging the batteries car. Every windshield of a car will be exposed to 60% of solar irradiation, is highly recommended for hybrid or electric car to install transparent solar system by replacing the entire window's car. The installation of transparent solar system can be one of the electrical source systems in hybrid car. This report stated the outcome of investigation on the performance of solar panel with respect to the sun irradiation and its energy consumption for hybrid car in analysis part. An alpha version of prototype has been made for the experimentation on hardware and collection data. 3 major step of methodology has been describe to make this project complete and working well, that are planning, construct and analysis. Finally, the contribution of transparent solar panel for hybrid car is about 0.5761kwh energy consumption which is can make the vehicle travel about 3 to 4km after one day under sun emission and less of 565g carbon dioxide release compare to the others gasoline cars.

ABSTRAK

Kereta hibrid dan kereta elektrik semakin banyak dipasarkan hari ini. Faktor pengeluaran kereta jenis ini sebenarnya disebabkan oleh dua sebab utama, iaitu mengurangkan kadar penggunaan petrol dan mengurangkan perlepasan gas rumah hijau. Umumnya kadar pencemaran udara dapat dikurangkan dengan menggunakan jalan alternative iaitu menghasilkan tenaga boleh diperbaharui daripada sumber tenaga yang bersih. Terdapat sistem sumber tenaga elektrik dalam kereta hibrid seperti sistem brek dan pusingan tayar yang bertujuan untuk menghasilkan tenaga elektrik supaya dapat mengecas bateri kereta. Setiap cermin kereta akan terdedah kepada 60% daripada sinaran matahari, dan adalah sangat disyorkan bagi kereta jenis hybrid atau elektrik memasang sistem solar lut sinar dengan menggantikan semua cermin kereta. Pemasangan sistem solar lut sinar ini akan menjadi sebahagian daripada salah satu sistem sumber tenaga elektrik dalam kereta hibrid. Laporan ini menunjukkan hasil siasatan telah dibuat terhadap prestasi panel solar dengan keamatan sinaran matahari dan penghasilan tenaga daripada sistem solar untuk kereta hibrid dalam bahagian analisis. Sebuah model versi alpha telah di bina untuk tujuan ujikaji dan pengumpulan data. Langkah-langkah yang diambil bagi menyiapkan projek ini telah di terangkan secara lengkap, antaranya ialah step perancangan, pembinaan, dan analisis. Akhir kalam, sistem solar lut sinar dapat menyumbangkan sebanyak 0.5761kwh tenaga, yang mana boleh menggerakkan kereta sejauh 3 ke 4 km pada satu hari berada di bawah sinaran matahari.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1.1 Introduction

Hybrid cars productions today are marketed by two major benefits, which are increased fuel economy and reduce greenhouse gases emission. Generally, hybrid cars produce 80% less harmful pollutants and greenhouse gases than comparable gasoline cars. This translates to eco-friendly system, and a cleaner earth. A hybrid car is driven by a hybrid engine, which is any engine that combines two or more sources of power, generally gasoline and electricity. Hybrid systems use batteries to store the sources of power to make the vehicle move, while braking system use to generate kinetic energy so that the batteries can recharged while driving [1]. In this report, the implementation of transparent solar panel to replace all windshield glass in hybrid car in order to be a part of electrical source system for charging the batteries.

Solar energy is a renewable energy, which has going to be progressively well known nowadays. It has noticeable healthy than non-renewable energy such as nuclear energy, coal and oil. It is can produce energy anywhere that there is sun shining and non-polluting, so its resources are not going to run out anytime soon. It also has advantages than other renewable energy such as water power and wind turbine. Sun power is generated using solar panel, no mechanical part are involve for generating an electricity like wind turbine. The mechanical parts produce noise or can be break down and cause maintenance issues. Both of these issues are virtually non-existent with solar panels. Beside, solar panels are also can last up to several decades without replacement. Because of these several reasons, it is better for hybrid car to install solar panel in its system for charging the batteries. This report will also discussed about selecting the best type of solar panel for windows, type of batteries, and calculation of energy consumption by solar cell and distance traveled by vehicle.

To begin the project, an alpha version of a prototype (hardware) needs to construct to study the performance of solar panel with respect to the sun radiation and its contribution (energy consumption).

1.2.1 Background

The sun is known to supply the world with a permanent and abundance clean energy source in the form of solar radiation. The measure of sun oriented radiation captured by the world's surface is 82×10^{15} W which is much higher compared to the annual global energy use [2]. Understanding this, researches have been widely done lately producing many promising technologies in order to extract the sun"s energy. Hybrid car have currently been introduced to the market. These hybrid cars have components such as a computer, inverters, a battery, and electric traction motors which can readily use photovoltaic generated electricity to produce propulsion.

In this chapter, there are discussing about the introduction of photovoltaic system in term of renewable energy and the improvement of electrical source system in hybrid car. The objective of the project is to understand in flow of the system. It started from, photovoltaic system, converter configuration, battery that can be used and compare to the recent hybrid car. Problem statement, objective and scope of the project will be explained in detail. Hybrid system, operation of photovoltaic will be explain and discuss deeply in Chapter 2.

1.3 Problem Statement

Energy policies and global warming have become a hot topic on the international issue. Advanced countries are trying to lessen their greenhouse gas outflows. Clean energy can be produce by a technological alternative such as renewable energy source. Over the renewable energy, photovoltaic system has received a big attention as it appears to be one of the most promising zero emission. Solar modules to vertical walls or facades had been widely used to produce energy. To avoid pollution caused by fossil fuels from the cars and to save fuel cost, hybrid system is the one of the best way to be installed for car. For construct model of the system, it required to understand the operation of solar system to meet the specification of hybrid car system. Lot of fundamental engineering knowledge is needed to begin this project.

1.4 Motivation

The car's windshield surface, which receives up to 60% of the solar radiation incident upon the vehicle glazing, is traditionally tinted, resulting in absorption but produce nothing. When solar radiation hits the car glass windows, 4% of radiation is reflected off the glass, another 3% absorbed by the glass, and 53% transmitted through the glass shows in figure 1.1.

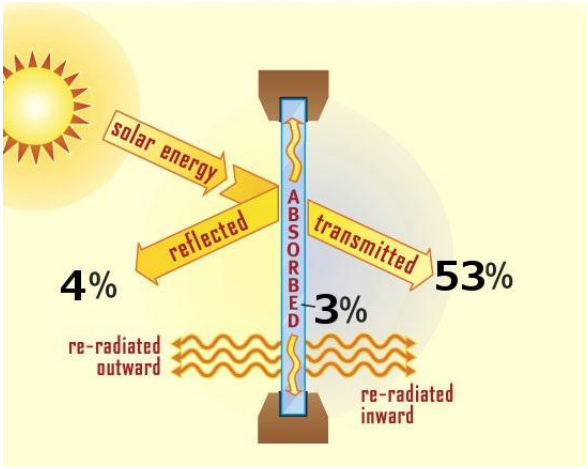


Figure 1.1: Windshield surface receives solar radiation

For these reasons, it is needed to design a PV integrated power source, to replace windshield glass so that it will utilize the wasted energy generated by sun to produce electrical energy to charge a battery of hybrid car. It is can be a new part of electrical source systems to improve the charging system in hybrid car. Before, hybrid car might have braking system to utilize kinetic energy or dynamo to generated electricity by rotation of tires or maybe solar panel on the roof top, but now then system will improved by installing the transparent solar panel for all glasses to optimize day light energy for charging the batteries during parked or driving under the sun. The motivation of this thesis, develop a photovoltaic solar panel in windshield glasses so that it will utilize the wasted energy produced by sun to produce electrical energy for charging a battery of hybrid car. It will be new part of electrical source system to improve the charging rate while generating clean electricity and eco-friendly system.

1.5 Objectives

Design and analysis of photovoltaic integrated charging system are the aims of the research. The photovoltaic integrated should be capable to meet specification of battery such as output power, voltage, and current. To achieve these aims, the objectives of this research are to:

I. Analyze the output value from model of solar charging system with using related theories and formula.

II. Analyze the operation of transparent solar panel that will be installing for charging system in hybrid car.

III. Investigate the performance of solar panel with respect to the sun radiation and its energy consumption.

1.6 Scope Of Projects

The scopes of this project are:

I. Developing a model of photovoltaic module that converts solar energy to electric energy.
   - Design a prototype of electrical system for charging batteries in small scale. Use batteries bank as a storage unit and solar panel as a generating system.

II. Determination type of photovoltaic cell that will be designed.
   - Study on the best type of photovoltaic cell for windows which are needs to be transparent and efficient. Understanding the suitable type of solar panel that can be selected.

III. Research on battery chemistries that suitable for hybrid car that can be able for solar panel to store the energy.
   - Investigate the suitable type of batteries used by electric motor of hybrid car. The percent of charged energy input by solar panel daily.

1.7 Project Conclusion

At the end of this project, the outcome to produce a charging system for hybrid car"s battery which is powered via transparent solar panel is recommended to install. Hybrid vehicles are able to make effective use of solar energy. Replacing all windshield glasses in hybrid car to utilize the sun energy, hoped these alternative and more environmentally friendly technologies may be implemented. Finally, a conclusion will be concluded to summarize the overall project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Today, hybrid electric vehicles are chosen for the option of the day and many automobile companies have their interest and asset in this area. The main reasons for this are for the coming energy crisis, and significant increase of greenhouse gases. The proposed system can produce power, without polluting the air.

Thus this chapter will explain development an electrical source system for electric or hybrid car which includes the solar panel and batteries as its input energy sources and the power electronic devices as connecting and transforming part. The transparent solar which is mounted with windshield absorbs solar energy during the day time to supplement energy cost of battery.

Then, type of solar cell, such as crystalline silicon solar cell and thin-film solar cells is studied and explained clearly. Lastly, this chapter explain about the designing an electric vehicle with a thin-film silicon photovoltaic cells to charge battery of hybrid car as well as to utilize the wasted energy.

2.2 Overview of Photovoltaic System and Earlier Researches

Photovoltaic cells are available in the market with different semiconductor materials. The most popular semiconductor materials for PV are monocrystalline, polycrystalline, thin film and copper-indium selenide (CIS). The technologies involved of p-n junction diodes capable of generating electricity from light sources and usually have efficiencies of 6% - 20% in market use [1].

Making of Monocrystalline and polycrystalline silicon arrays are almost the same way. There are made up of individual 0.5 V cells connected together to achieve the required power [1]. Their weigh less than the amorphous and CIS arrays, and are about half the size of CIS arrays in which to produce the same power.

Microcrystalline silicon carbide (μc-SiC:H) thin film, CIS thin film and amorphous thin film are the most popular type of Thin Film PV technologies. Thin film be made up of a layer of silicon fabricate with glass and plastic [2].]. A laser scribe is then used to mark out individual cells. Thin film cell generate very good energy consumption on sunny days compare to other crystalline silicon cell. However thin film need to be bigger in size than other crystalline silicon cell in way to produce the same energy.

Basically one single cell can produces about 0.5 volt and then they are connected together to form modules (combination of 36 cells). Combination connected of modules can form larger units called arrays as shown by Figure 1.1.

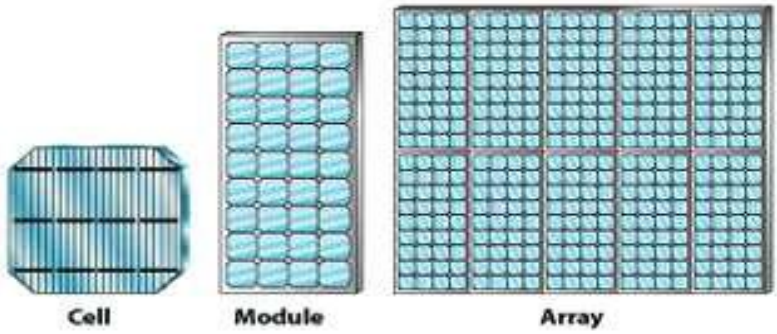


Figure 2.1: Arrangement of PV Cell, Module and Array [3]

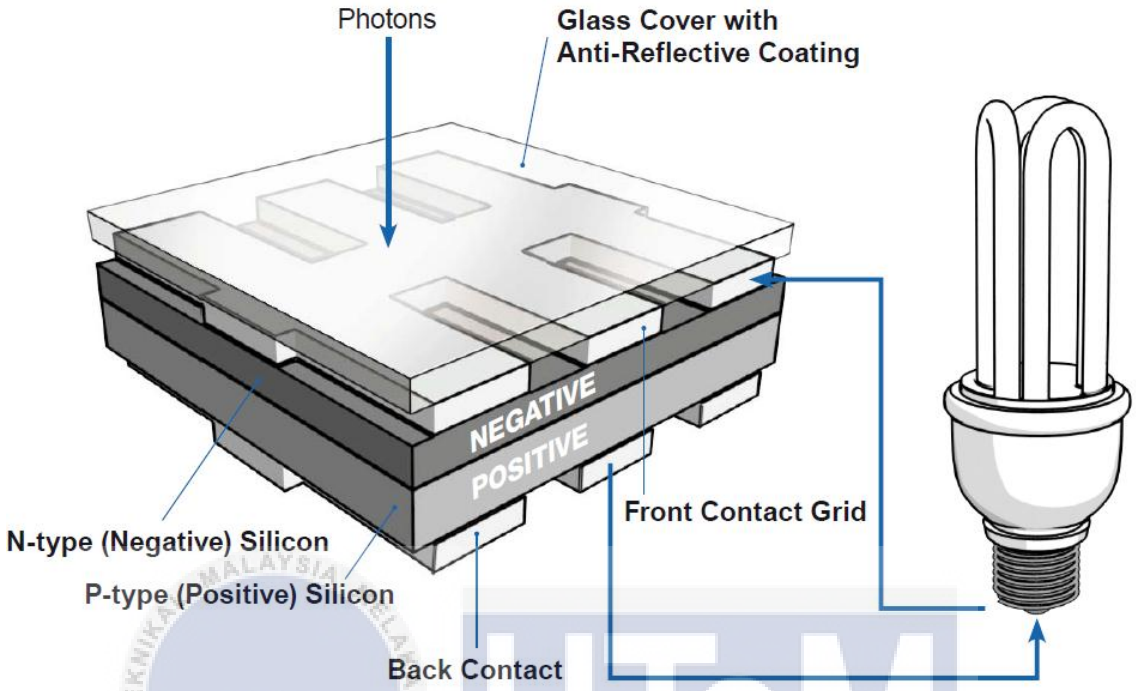
2.3 Principle of Solar Cell

A photovoltaic or solar panel is made up of several photovoltaic solar cells. A cell of photovoltaic normally generates about 1 or 2 watt of power [3]. Energy is generated when photons of light from the sun collides a solar cell and are captivated inside the semiconductor material. This energizes the semiconductor‟s electron, result in the electrons to discharge, and produce an electric current [3]. The electricity generated is direct current (DC) since the flow of charge is in one direction. To increase the output power of PV cells, they are connected together to form larger units. This joined cell is call array, and the combination between arrays are called module. Producing module is to produce more power, and so on. Therefore, photovoltaic systems can be built to meet all electric power need, small or large.

2.4 Structure of a Solar Cell

Solar panels, from the very small ones used in some calculators, to the much larger ones found on some suburban rooftops, are made up of various numbers of photovoltaic cells. These cells, also known as solar cells, make use of a natural energy source, the sun, to generate electrical power without any moving parts, noise, pollution, radiation or the need for maintenance [5]. A solar cell is formed by a composition of materials typically made up of the following layers:

I. Glass cover with anti-reflective coating
II. Front contact grid
III. N-type (negative) silicon
IV. P-type (positive) silicon
V. Back contact grid.



Picture 2.2: Typical Solar Cell Structure [4]

When photons that are light from the sun strike the cell, they give up their energy to electrons in the P-type layer causing them to jump to the N-type layer (positive to negative). This transfer of electrons forms a current which flows from the „back contact grid" through a circuit to the „front contact grid. A number of solar cells can be wired together into a solar panel to increase the voltage as may be required for different applications such as household hot water heaters and solar powered cars [6].

2.5 Crystalline Silicon (c-Si)

The popular choice of solar cell material is silicon because it‟s inherent physical quantities. Silicon has 4 valence electrons from an 8 „holes‟. It will always attract to fill the other 4 „holes‟, thus the hole will sharing electrons with another silicon atoms [5]. A lattice type structure then created after the sharing proces, where every atom in the structure bonds with four other atoms in the structure.

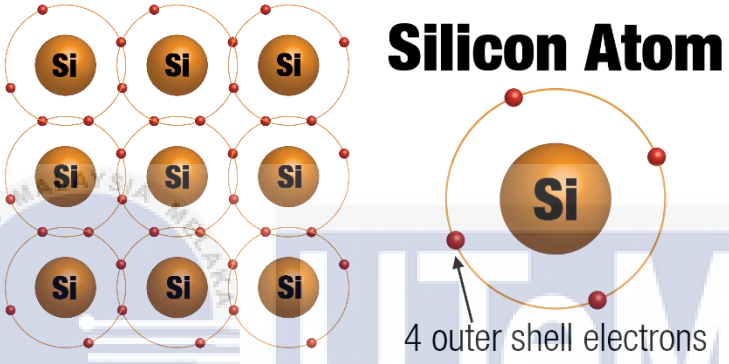


Figure 2.3: Structure of Silicon Atom bonds with four other atoms [5]

Under the sun emission days, energy is added to silicon material. Then the electron will be knock out and free from lattice structure, but this proces need a lot of energy and produce very few free electron. As the free electron release from lattice, there is small current flow. Therefore, some impurities are added to increase its current. The process of added impurities to the silicon is called doping process [5].

Atom consist of more electron is „doped‟ into the silicon materials to create negative charge of silicon or atom that consist of less electron is doped to create positive charge of silicon. These compounds are n-type and p-type [5].

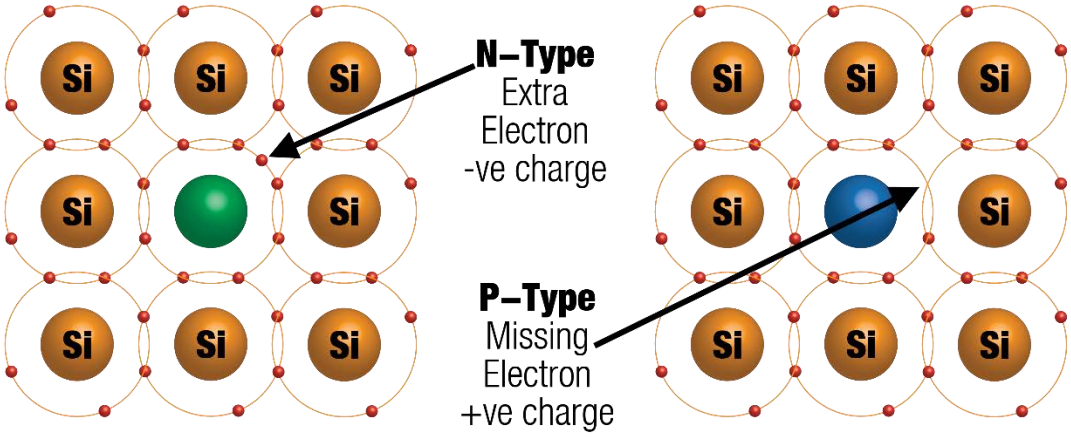


Figure 2.4: Number of P-type and N-type Silicon Atom Electron [5]

If the N-type get energy, there will be lot free electron produced in the structure. Then, this N-type silicon is placed next to the P-type silicon so that the free electron can get into the hole in P-type silicon, and then generate a current flow [5].

2.5.1 Mono-crystalline Silicon Solar Panel

Single silicon crystal can form a Mono-Crystalline panel. Silicon crystal can get either made in a laboratory of found naturally (hard to find). Process of create this crystal is called recrystallizing, which is tough to produced and then will make the Mono-crystalline panels more expensive. The interface of Mono-Crystalline is smoother than poly- Crystalline panel, as shown in figure 2.5. Normally Mono-Crystalline efficiency is around 15% at 25°C, and then drops at 50°C by 12% to 15% [7]. Therefore, the higher temperature of the panel gets, the lower the efficiency of the solar panel.

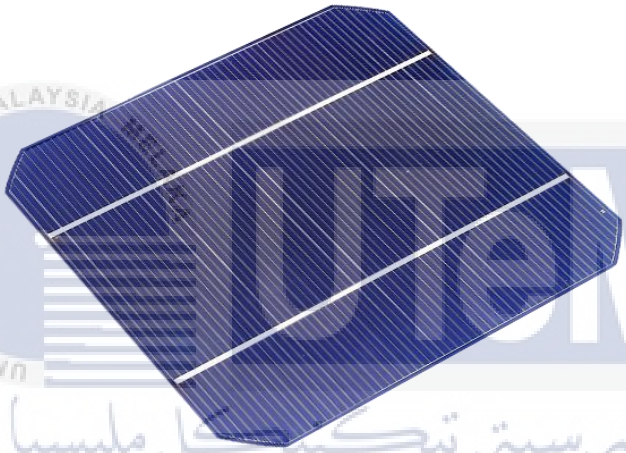


Figure 2.5: Mono-crystalline Silicon Solar [7]

2.5.2 Poly-crystalline Silicon Solar Panel

If the Mono-Crystalline is form by a single crystal, block-cast of silicon crystals is then use to create a Poly-Crystalline panel. Because of that, a metal- flake effect will appear on the panel, as shown in figure 2.4. In a Poly-Crystalline panel, the crystal grain boundaries between the single crystals cause the electron trapped. On that reason, the panel will get lower efficiency rating. However, the cost of making Poly-Crystalline is much cheaper than Mono-Crystalline. Normally, the efficiency rating of Poly-Crystalline is around 13.5% at 25°C, and will drop by around 15 – 25% at 50°C [6].

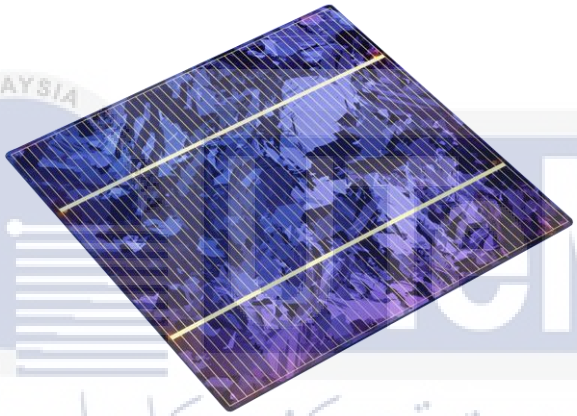


Figure 2.6: Polycrystalline Solar Cell [6]

2.6 Thin-Film

Thin-film solar panels are manufactured by transferring one or a few coats of photovoltaic material onto a wafer. Most of thin film solar cells are categorized to one of these groups:

I. Amorphous Silicon (a-Si)
II. Cadmium telluride (CdTe)
III. Copper Indium Gallium Selenide (CIGS)
IV. Organic Photovoltaic Cells (OPC)

Early pattern of thin-film module have shown efficiencies in the range of 7-13% and about 9% for manufactured modules. Imminent module efficiencies are predicted to reach about 10-16% [7]. An active thin film silicon solar cells layer‟s thickness is less than 1 micrometer. Today‟s technologies are potentially to produce a thin film solar panel from combination of lower cost materials such as toxicity of components and limited supply of basic materials, and still can generate the desired energy. Amorphous silicon technology is the oldest and best established thin-film silicon technology.

2.6.1 Amorphous Silicon Solar Cell

One of thin-film technology is an amorphous silicon panel, made up by layer of photovoltaic material applied to the panel‟s substrate. It is consisting of less silicon than crystalline panels, which cost of making will be reduced. The process of making amorphous silicon panel is almost automated. Deposition of silicon to form gas then fabricate on a substance like glass. Amorphous silicon cell is not sensitive to partial shading like others crystalline cell. The layer of amorphous material caused the panel to be more flexible in the layout. The long flat cells over the board make them less powerless from being hindered by shade. Efficiency of amorphous silicon cell is less than others crystalline panels. The bigger size of thin film panel is required to produce the same energy of others crystalline panels.

Figure 2.7: Amorphous Silicon Solar Cell [9]

2.6.2 Cadmium Telluride Solar Cell (CdTe)

Today"s production of CdTe solar cells is decreasing. It is because making of CdTe is used Cd one of the element abominable in periodic table. However, it is easy to make CdTe cell and the cost also cheap. The genuine issue comes from the way that all of the solar panel industry must consider how to reuse their items at the end.

Figure 2.8: Cadmium Telluride (CdTe) Solar Cell [9]

2.7 Backup Battery

It is important to store energy utilize by solar panel in the back-up batteries. A backup battery can demonstrate exceptionally valuable as it can store any unused power produced by the solar panel for daily and thus, this store energy can be utilized to power electrical device when no daylight is accessible to the solar panel, hence making the device more reasonable. The most reasonable decision for this storage device is a backup battery [11]. There are a wide range of backup batteries accessible available today, with different distinctive battery chemistry. Various battery chemistry that was looked for utilization in this project are talked about, highlighting the preferences and detriments of each.

2.7.1 Nickel Cadmium (NiCad)

Nickel-Cadmium batteries have an enduring and can be left to store power for up to five years now and again. They have different preferences also, they incline toward quick charging and function admirably under thorough conditions, and in addition having truly a high efficiency at 70% - 90%. Nonetheless, they have a moderately low power to weight proportion and can experience the ill effects of memory impact. Memory impact is a marvel saw in some rechargeable batteries, specifically those with nickel-cadium chemistry. It happens when the rechargeable battery is over and again revived without being completely released [11]. This causes the battery to lose the limit it initially had, and the execution of the battery is fundamentally brought.

2.7.2 Nickel Metal Hydride (Nil MH)

Ni-Mh based battery have a bigger limit then the Ni-Cad batteries, so they are lighter, and are less inclined to the memory impact depicted previously. Notwithstanding, they can be more costly and have a moderately short life existence with a high self-discharge rate, making them less efficient [11].

2.7.3 Lithium ion (Li-ion)

Li-ion is the best efficient batteries compare to all type of battery cell with efficiency of 99.9%. Beside, Li-ion also has light weight than the others, it is about half of Ni-Cad and Ni-Mh cell size at the same capacity. One cell of battery can produce output voltage around 3 to 4 Volt. Constant current is required for charging the battery while input voltage is rise. It seem like Li-ion battery is the most suitable for storage system.

2.8 How Hybrid Cars Work

The operation of a hybrid car is using hybrid engine, which gasoline and electricity as source of power. Parallel hybrid and series hybrid are two type of hybrid car. Both use gasoline-electric hybrid technology, but in radically different ways [13].

For parallel hybrid car, an electric motor and a gasoline engine run simultaneously for car to moving forward. For series hybrid car, gasoline engine is use to generate electric for power the electric motor or for charging the batteries. Regenerative braking is a process to store kinetic energy in batteries, generated while using brake. Both types of hybrid car use this process for charging its batteries.

Both types have compact gasoline engines cause the pollution less than standard gasoline cars and also create less power. Generally power generates between 60-90 horsepower, while standard gasoline cars create double of that. To overcome this power gap, hybrid cars are constructed with ultra-lightweight materials like carbon fiber or aluminum. Hybrid cars are also designed to be more aerodynamic than most cars, allowing them to "slice" through air instead of pushing it out of the way. All these factors combined equate to a super-efficient form of car that gets excellent fuel economy and helps the environment by cutting down on pollution [13].

2.9 Thermoelectric generator work

Temperature differences between both sides of thermoelectric generators turn it into electrical power. Heating one side of a thermoelectric material causes the electrons to move away from the hot side toward the cold side. When the electrons go from the hot side to the cold side this causes an electrical current, which the PowerPot harnesses to charge USB devices. The larger the temperature difference the more electrical current is produced and therefore more power generated.

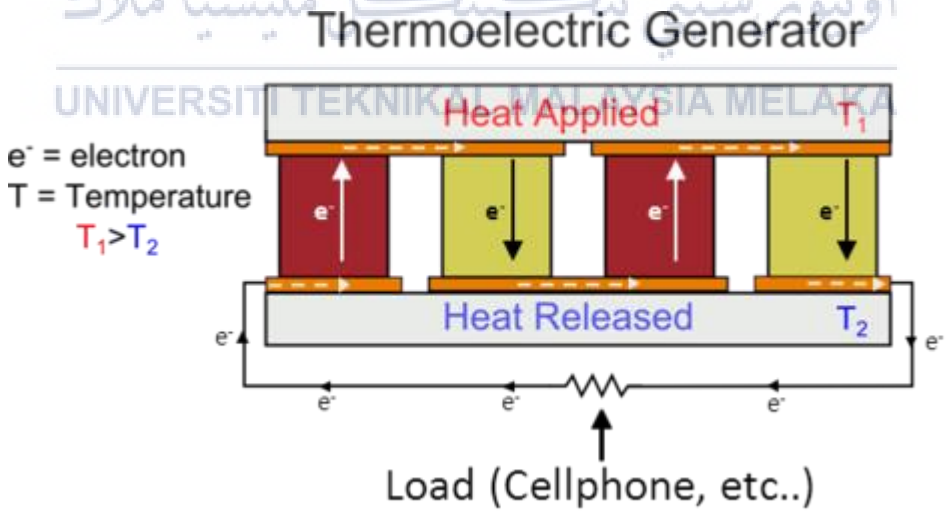


Figure 2.9: Thermoelectric generator configurations

2.10 Summary of Literature Review

In this chapter, all the theories and literature review about the project has been stated and elaborated. The first part of this chapter explains about system component including the major part of the solar system and thermoelectric generator. All type of solar cell has been review and discussed. For next part, it discuss about operation of hybrid car and it benefit. Finally, from all review discussed it is shows that thins film cell has been selected for making the small scale charging system for prototype model and lithium ion batteries as a storage.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Details explanation of methodology has been describe to make this project complete and working well. Many findings from this project mainly produced from journal for others to take advantages and put some improvement for future research. Stage by stage method is use to achieve the objective of the project that will achieved a perfect result. This chapter describes further more about the planning of the whole project that is included prototype (hardware) development. Here I will discuss about the planning for project, selected type of solar cell and type of battery, and state Project Gantt chart and Key Milestones that will be used as a guideline. In order to finish this project, the method to "Development of PV Integrated Charging System for Rechargeable Lithium Ion Battery of Hybrid Car", generally three major stage is organized, which is planning, construct and analysis.

3.2 Project Flow Chart

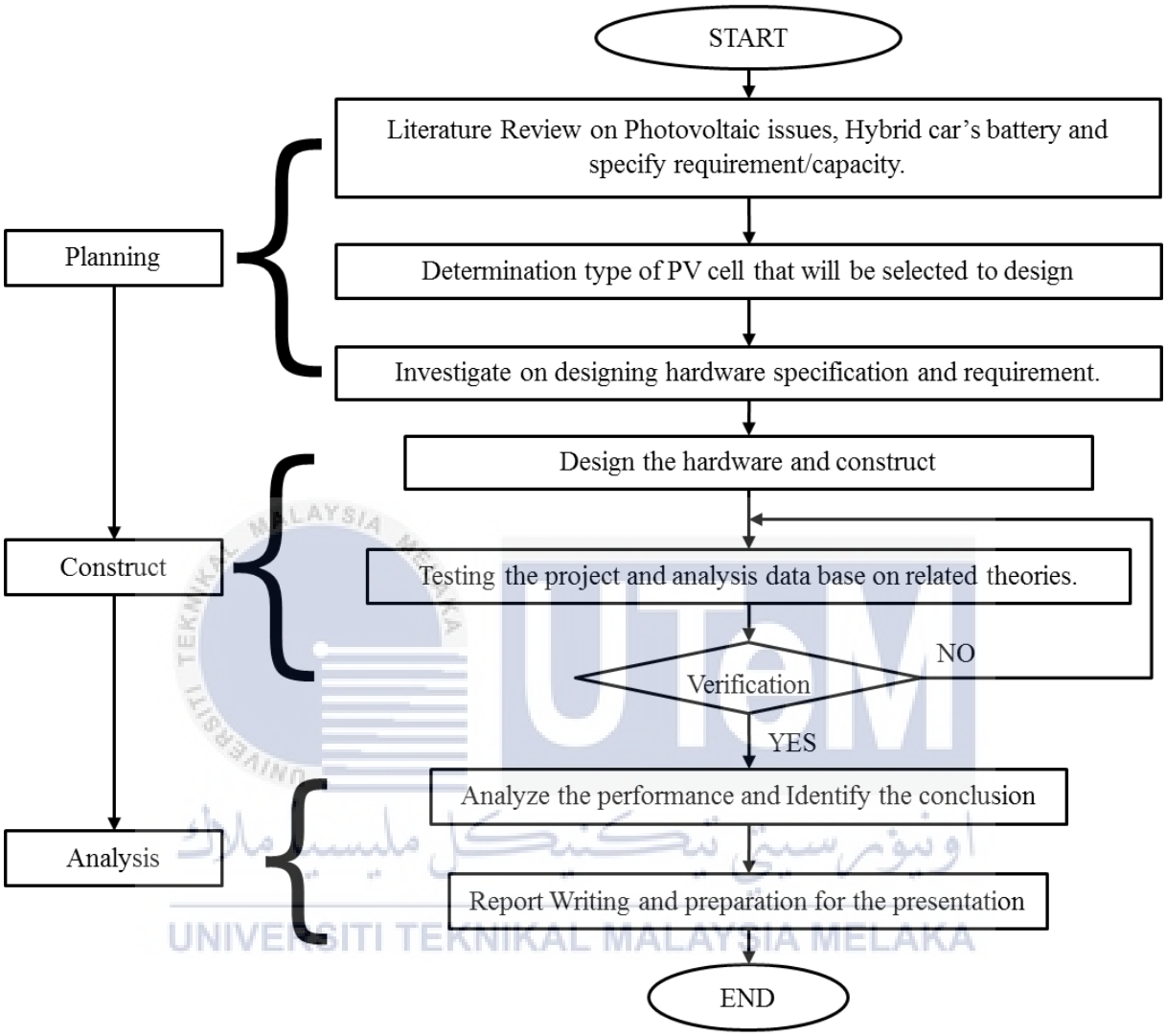


Figure 3.1: Project flowchart of the "Development of PV Integrated Charging System for Rechargeable Lithium Ion Battery for Hybrid Car"

3.3 Planning

To classify all the information and requirement for construct hardware and analysis, planning must be arranged in the proper manner. The stage of planning has three main elements namely literature review, determination type of PV and investigate on designing hardware.

3.3.1 Literature Review

The first step is study on the previous project, journal and books that related to this project which is the basic operation and theory of photovoltaic cell, principle of electrical and structure. This step has been further discussed at the previous chapter.

3.3.2 Determination type of PV cell that will be selected to design

In this step, the selection of photovoltaic cell use in the project is been discussed to select the best type of photovoltaic cell. With the choice of efficiency, low cost and flexible cell types selected, it is important to determine exactly what type of photovoltaic to employ. The factors that go into selecting an appropriate type of photovoltaic are similar to factors that went into selected an appropriate energy source, cost of materials and suitability based on the environment.

The types of photovoltaic considered were Monocrystalline Silicon cell, Polycrystalline Silicon cell, and Amorphous Si thin-film. They all have very different efficiency and as such, the cost of materials varies quite significantly. Furthermore, each of these solar cell types is optimal for certain ranges. Between these two factors, it is relatively simple to select an appropriate type.

With the literature review and comparison in mind, it is possible to determine the various solar cell types to see which is the most appropriate for the situation. Due to the low voltage generated in a photovoltaic cell (around 2.0V), several photovoltaic cells are connected in series (for high voltage) and in parallel (for high current) to form a photovoltaic module for desired output. Thin film Solar cell has been choosing after considered the necessary needed has mentioned before. Besides, thin-film solar cell can be flexible so that it can easily attach to the top of prototype‟s windshield. The following Figure 3.2 and Table 3.1 gives the various specifications of thin-film solar cell selected.

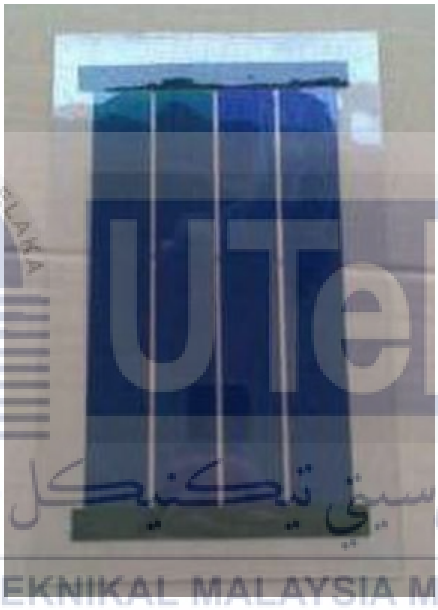


Figure 3.2: Amorphous Silicon 1W 6V Flexible Solar Panel

Table 3.1 Specifications of Solar Module

	Technology	**Thin Silicon Film**
1.	Model	Flexible, Amorphous Silicon 1W
2.	Nominal Power	1.0 Watt
3.	Max. Power Voltage	6.0 Volt
4.	Max. Power Current	0.2 Amp
5.	Open Circuit Voltage	7.0 Volt

3.3.3 Investigate on designing hardware

Investigate on designing hardware specification and requirement including PV thin film and lithium ion battery, arrangement, PV topology, and Battery material. The outputs of the prototype being observe and analyze. The analysis is to see whether the output produced is same with desired output in term of voltage, power and current base on theories related. Below is the list of the components and the material that will help to construct this project model.

I. Semiconductors

Capacitor - 100uF 25V 85ºC Radial Electrolytic Cap

Diode - IN5818 Shottky Barrier Diode

II. Resistor

R1 - 15K ohm ¼w 5% Carbon Film Resistor

R2 - 150K ohm ¼w 5% Carbon Film Resistor

R3 - 20K ohm ¼w 5% Carbon Film Resistor

III. Additional Parts and Materials

USB connector – Male and Female

Copper wire for connection

Strip board

3.4 Construct

During this part, all the electronic components are assembling on board and will be installing to model of prototype then ready to test.

3.4.1 Design and construct the hardware

The most important thing in this chapter is to build the project depends on selected type of solar panel and selected type of Hybrid car"s battery which can generate suitable output voltage, current and power depend on 6 hours of sunshine per day. In the first stages of the project several design solutions were drawn. The first design solution can be seen in Figure 3.3.

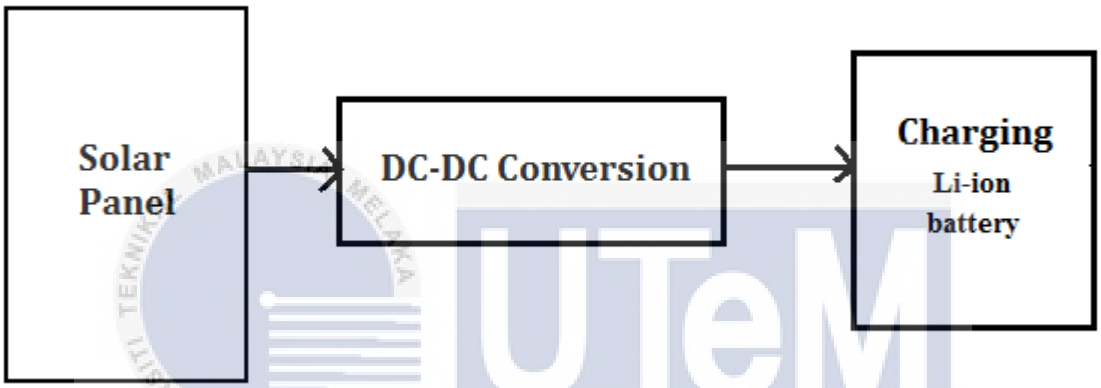


Figure 3.3 Design charging Li-ion battery

It is embodied a solar panel whose voltage is controlled by a DC-DC converter. It was chosen that the DC-DC converter would need to be assembled in the lab, as it was hard to locate a suitable marketed converter that could be controlled along these lines. The output of the converter is then connected to the Lithium ion battery. The configuration undertaking is made out of the accompanying part:

1. The PV modules which consists of the PV array.
2. A DC-DC Converter that increases or decreases the PV output Voltage in order to charge the batteries at a constant voltage.
3. Storage Battery which is to store energy generated by the Photovoltaic cell.

The hardware part will design using Solid Work Program. SolidWorks is a solid modeler, and utilizes a parametric feature-based approach to create models and assemblies. The software is written on Parasolid-kernel. All figure of designed prototype using Solid Work program and description will elaborate more in Chapter 4 letter.

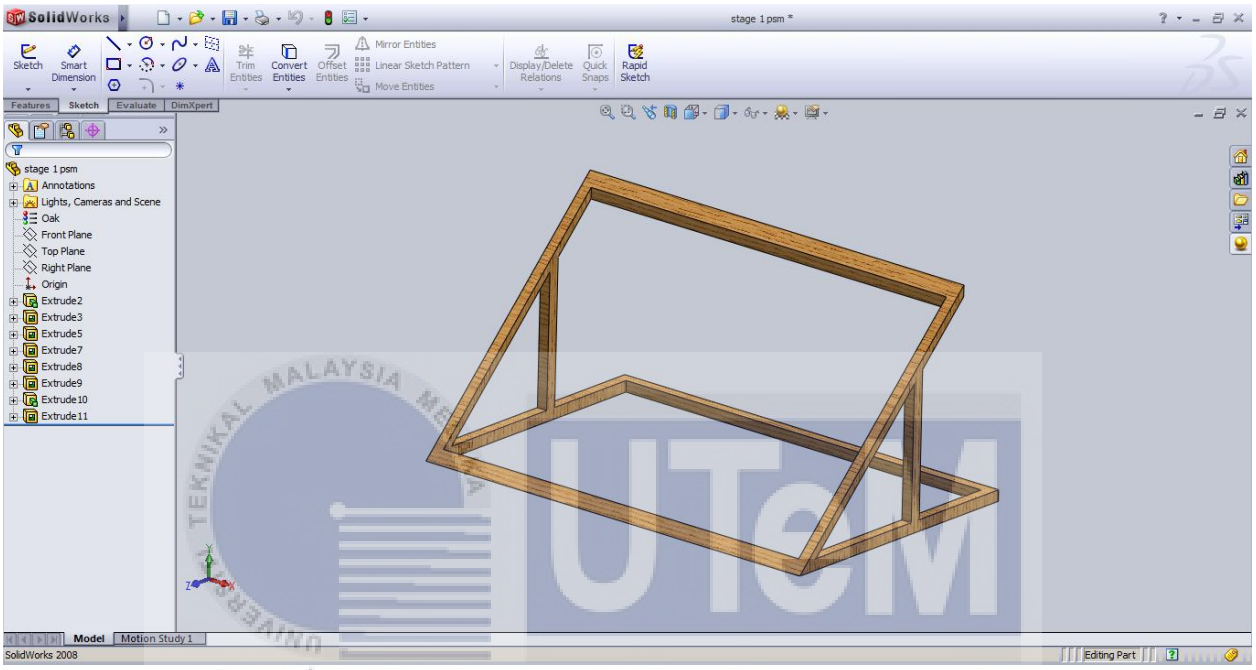


Figure 3.4 The Structure of Designed Model of prototype version in Solid Work

3.4.2 Testing the project and analysis data based on related theories

Hardware testing is important to detect the problem arise and troubleshoot the problem. The procedure of testing is started with connection between output of solar panel and batteries storage. The energy consumption by solar cell is defined by using global formula to predict the electricity generated in output of a solar panel system is

$$E = A \times r \times H \times PR \quad (3.1)$$

The relationship between power consumption by solar cell and irradiance of sun power can be determined.

3.5 Analysis

After assembling the hardware and testing, the analysis will be conducted to determine whether the measured value is valid as the theoretical value by using related equation. This project also analyzes material that used from past research to find the energy consumption of the transparent solar panel.

3.6 Report writing

The report writing will be conducted together with the final presentation after the result of the analysis is obtained. The findings of the proposed research will be documented in technical papers and research report for publications.

CHAPTER 4

RESULT

4.1 Introduction

This chapter will present about the result obtain. Results of this project are basically the output of the hardware and analysis from past research about transparent solar panel. The analysis is based on the result get from the output and the factor that need to be considering during this project implementation.

4.2 Result from Prototype Model (hardware)

To developing of photovoltaic and thermoelectric generator integrated charging system for rechargeable Lithium ion Battery of hybrid car, an alpha version of a prototype has been design and assembles as shown from Figure 4.1 to Figure 4.6 stage by stage. The designed hardware part was constructed using Solid Work Program. It is important to set up the prototype version because the need of study in performance of solar panel with respect to the sun radiation and its contribution.

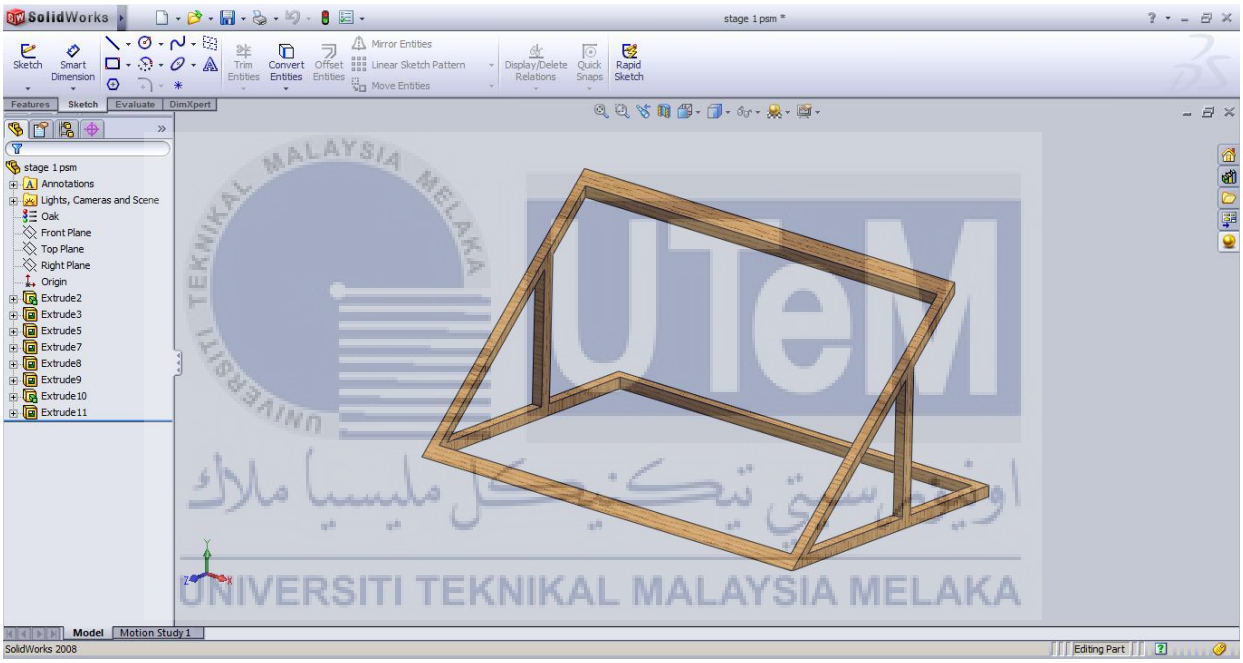


Figure 4.1: The foundation of hardware for stand the glass and roof in Solid Work

Figure 4.2: The Framework of hardware were assembled

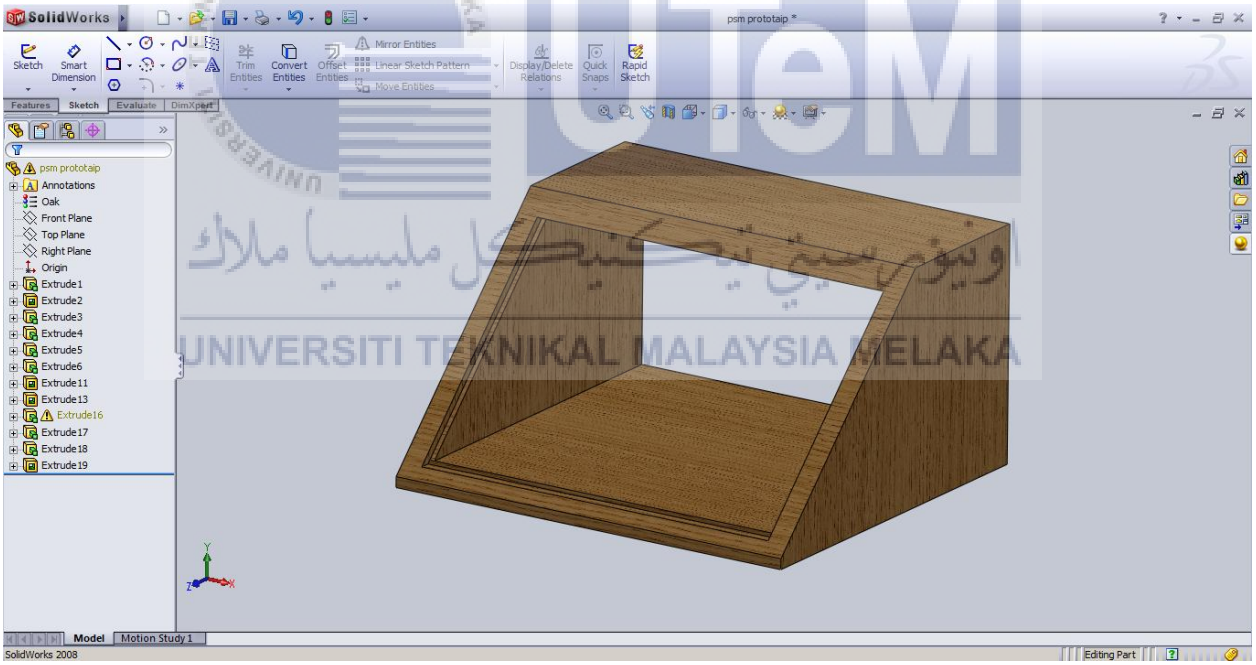


Figure 4.3: The plane wood was attached to the framework in Solid Work

Figure 4.4: The plane wood was assembled to the framework

Figure 4.5: An alpha version of a prototype has been completely designed

Figure 4.6: An alpha version of a prototype are ready to tested

4.3 Measurement and Calculation value

Table 4.1: Data Sheet of Amorphous Silicon 1W 6V Flexible Solar Panel

Maximum power STC (P_{MAX})	1.2W
Optimum Operating Voltage (V_{MP})	6 V
Optimum Operating Current (I_{MP})	200 mA
Open circuit Voltage (V_{OC})	7.70 V
Short circuit Current (I_{SC})	220mA
Dimension	0.21m X 0.13m X 0.001m

Table 4.1 shows the data sheet Data Sheet of Amorphous Silicon 1W 6V Flexible Solar Panel that is already in market. The experiment has been carried out to find the energy consumption by solar panel and the results were expressed in Table 4.2.

Table 4.2: Measured Value of Flexible Solar Panel

Output Voltage, V_{OP}	7.72 V
Output Current, I_{OP}	220 mA
Power, Watt	1.694 W
Irradiance (W/m^2)	782 W/m^2
Energy Generated per day, mAh	990 mAh

Some calculation has been done to verify the data required by experimental method.

Total power, P_T = (220mA)(7.70 V) = 1.694 W

Fill factor, FF $= \frac{P_{max}}{P_T} = \frac{(I_{MP})(V_{MP})}{(I_{SC})(V_{OC})}$

$= \frac{1.2W}{1.694W}$

= 0.708 or 70.8%

Efficiency, n $= \frac{(I_{MP})(V_{MP})}{G\,A}$ X 100 , where G is irradiance.

$= \frac{1.2W}{(1000kwhm^{-2})(0.0273m^2)}$ X 100

= 4.4%

Energy generated by solar panel, E = (P_{MAX}) (Solar Irradiance) (Loses)

= (7V X 440 mA) (4.9kWh/m^2) (1)

= 0.0151 kWh

The above data shows that the energy generated by solar panel in alpha prototype hardware is 0.0151kWh. This energy may contribute to the electrical source system in hybrid car to charge or powering small electronic device such as mobile phone, FM radio, and reading lamp. It is prove that the solar radiation in Malaysia is suitable to utilize as a clean energy for charging Lithium ion Battery in hybrid car.

Table 4.3: Measured Value of Thermoelectric Generator (TEG)

Temperature Diff ΔT (˚C)	**Current, I_o (mA)**	**Voltage (V_o)**	**Power (P_o)**
10	0.138	0.138	0.019
20	0.304	0.298	0.091
30	0.424	0.415	0.176
40	0.540	0.530	0.286
50	0.674	0.659	0.444
60	0.829	0.811	0.672

The Thermoelectric will be attached to the car‟s windshield, the number of thermoelectric generator units and the power generated is as follows:

Front Windshield : 97 Units, 8.787 Watt

Back Windshield : 95 Units, 8.606 Watt

Total : 192 Units, 17.4 Watt

4.4 Result from Past Research about Performance of Transparent Solar Panel

As the window layer for solar cells, the material needs to be both conductive and transparent. Microcrystalline silicon carbide (μc-SiC:H) thin films are an excellent window layer for thin film solar cells. The experiment on Microcrystalline silicon carbide thin films has been carried out by Prof. Tao Chen [16] and the parameters were stated in Table 4.3. Some calculation has been made to measure fill factor, efficiency, and total power of solar cell. The relationship between energy consumption by solar cell and distance traveled by vehicle will be present, and will be compared with the related car. The energy consumption by solar cell is defined by using global formula to estimate the electricity generated in output of a photovoltaic system is E = A * r * H * PR. Finally, the total cost of fuel that can be save if this transparent solar panel is applied on hybrid vehicle.

Table 4.4: Parameters of Tested Microcrystalline Silicon Carbide Thin Films Cell.

Parameters	Value
Area of tested Cell, 1cm x 1cm	0.01 m^2
Window layer thickness	18 nm
Short circuit current density, J_{SC}	11.8 mA
Open circuit voltage, V_{OC}	548 mV
Optimum operating voltage, V_{MP}	452.65 mV
Short circuit current, I_{SC}	11.8 mA
Optimum operating current, I_{MP}	9.2125 mA

4.4.1 Calculation

Total power, P_T = (11.8mA)(548mV) = 6.446mW

Maximum power, P_{max} = (9.2125mA)(452.6mV) = 4.2161mW or 0.000042161kW

Fill factor, FF $= \frac{P_{max}}{P_T} = \frac{(I_{MP})(V_{MP})}{(I_{SC})(V_{OC})}$

$= \frac{(9.2125mA)(452.6mV)}{(11.8mA)(548mV)}$

= 0.652 or 65.2%

Efficiency, n $= \frac{(I_{MP})(V_{MP})}{G\,A}$ X 100 , where G is irradiance.

$= \frac{(9.2125mA)(452.6mV)}{(1000kwhm^{-2})(0.001m^2)}$ X 100

= 4.2%

To calculate the energy consumption by solar panel, the total area of all windows surface need to determine first. From the Toyota Prius data sheet;

I. The area of front windshield, $A_1 = 0.917m^2$
II. The area of rear windshields, $A_2 = 0.8382m^2$
III. The area of front right windshield, $A_3 = 0.2813m^2$
IV. The area of front left windshield, $A_4 = 0.2813m^2$
V. The area of rear right windshield, $A_5 = 0.243m^2$
VI. The area of rear left windshield, $A_6 = 0.243m^2$

Note: Using Toyota Prius window's surface area because Prius are relevant to market potential as hybrid car.

Total Area, A_T $= A_1 + A_2 + A_3 + A_4 + A_5 + A_6$

$= 0.917m^2 + 0.8382m^2 + (2 \times 0.2813m^2) + (2 \times 0.243m^2)$

$= 2.7885m^2$

E = A * r * H * PR

Where;

E = Energy (kWh)

A = Total solar panel Area (m^2)

r = solar panel yield (%)

H = Yearly Solar Irradiance in Kuala Lumpur = 4.9 kwh/m^2

PR = Performance ratio, coefficient for losses = 1 *assume in ideal condition

$E = (2.7885m^2)\left(\frac{0.0000042161kW}{0.0001m^2}\right)(4.9\ kwh/m^2) = 0.5761kwh$

4.4.2 Analysis & Discussion

Based on the JC08 Japanese test cycle [17], the Prius Plug-in Hybrid with a 4.4-kWh lithium-ion battery that allows an all-electric range of 26.4 km. Therefore, 0.5761kwh output power from solar panel can make Toyota Prius travelled about 34.56 km (EV mode condition). After the battery has been depleted, the HV mode fuel efficiency is 31.6 km/L. Then, if Prius Plug-in Hybrid in combined all-electric (EV) and hybrid (HV) driving modes, the fuel efficiency is 61.0 km/L and the electric motor power consumption rate is 8.74 km/kWh. Thus, 0.5761kwh output power from solar panel can make this vehicle travelled about 5.035 km with use 0.0825 liters gasoline. The comparison value between EV mode, HV mode, and both EH and HV mode of Prius Plug-in Hybrid are presented as a detail below.

Condition of Vehicle: Electric Vehicle, EV mode

Rate of car:	1 kWh	→	6 km
From Solar:	0.5761kwh	→	3.457 km

Condition of Vehicle: Hybrid Vehicle, HV mode

Rate of car:	1 Liter	→	31.6 km
From Solar:	3.457 km	→	0.11 Liter

Condition of Vehicle: EV and HV mode

Rate of car:	1 Liter	→	61.0 km
Rate of car:	1 kWh	→	8.74 km
From Solar:	0.5761kwh	→	5.035 km
From Solar:	5.035 km	→	0.0825 Liter

From above data, it shows there is no big contribution from solar panel to charge the lithium ion batteries cell. It is because the estimation of energy base on calculation directly from solar panel to batteries. Actually, the calculation need to consider that the solar system also has booster device to step up the energy from solar for the lithium ion batteries, so that it can charge a lot of energy. Besides, if the comparison of carbon dioxide, CO_2 release between hybrid car and gasoline car, it shows lot of significant. The CO_2 release from Toyota Prius is only 190g for 5km travelled while the others gasoline cars such as Perodua Myvi release about 755g CO_2. Therefore, the project had archives the aim to reduce greenhouse gas emission by producing clean energy from renewable energy source for charging system in hybrid car. Hence, it very recommended for hybrid vehicle to install these transparent solar windows so that it can be a part of electrical source system to charge the batteries.

CHAPTER 5

CONCLUSIONS

5.1 Conclusion

In this section will firstly state about the project. The knowledge gains through the process and theories on the photovoltaic and the design the prototype hardware. The next will be recommendation section that recommends some improvement on electrical system in hybrid car. The project firstly has been able to archive the primary which assembly alpha prototype (hardware) of solar panel system. The prototype begins with design 3D model in Solid Work program to see the „big picture" of the hardware part. The operation of solar panel and hybrid car systems are needed to take attention. These vehicles extend the functionality of traditional internal combustion engines by combining them with a battery-powered electric motor, which takes some of the work off the combustion engine"s hands. Lastly, the investigation on performance of solar panel with respect to the sun radiation and its energy consumption were successfully done.

5.2 Achievement

There are several achievements had been discover through this project such as:

1. Participated in The National Innovation And Invention Competition Through Exhibition, iCompex‟15 on 24-26 March 2015, at Politeknik Sultan Abdul Halim Mu‟adzam Shah, Jitra, Kedah (Bronze Medal).
2. Participated in International Engineering Invention & Innovation Exhibition, i-Envex 2015 on 17-19 April 2015, at Universiti Malaysia Perlis (Unimap) (Silver Medal).
3. Participated in UTeM-Infineon Technical Poster Competition on 3 Jun 2015 at Faculty of Engineering Technology, UTeM.
4. The system will be protected by MyIPO, and the Copyright registration is shown in Appendix A.

5.3 Recommendation

This Project has been achieved the objective and scope, but some improvement could be made to upgrade the system, especially on the hardware part. The hardware part only use the flexible solar panel so that it easily to attach to car‟s windshield. It is because the curve of windshield glass makes the flexible solar panel suitable to match the specification. For future improvement on the hardware part, it strongly suggest that the use of Microcrystalline silicon carbide (μc-SiC:H) thin films as a material for testing. It is because a Microcrystalline silicon carbide (μc-SiC:H) thin film is an excellent window layer for thin film solar cells.

REFERENCES

[1] Anonymous, Hybrid Car Emissions Information. Hybrid Car Information and Resources, [online]. 4 (2). Available at: http://www.hybrid-car.org/hybrid-car-emissions.html (Hybrid Car Organization) [accessed 22 May 2015]

[2] Hassan, H. Z., Mohamad, A. A., & Bennacer, R. (2011). Simulation of an adsorption solar cooling system. Energy, 36(1), 530-537.

[3] El-Arini, M. M., Othman, A. M., & Fathy, A. (2013). A New Optimization Approach for Maximizing the Photovoltaic Panel Power Based on Genetic Algorithm and Lagrange Multiplier Algorithm. International Journal of Photoenergy, 2013.

[4] Al-Karaghouli, A., & Kazmerski, L. L. (2011). Renewable Energy Opportunities in Water Desalination. Golden, Colorado, 80401.

[5] Edward Caddy, Bowie, MD 20721, Photovoltaic for Hybrid Automobiles, May 11-18, 2003.

[6] Vineeth .V Vincent,S.Kamalakkannan, Advanced Hybrid System for Solar Car, 2013.

[7] Bin Wu, Fang Zhuo, Fei Long, WeiweiGu, Yang Qing, YanQinLiu"A management strategy for solar panel battery -super capacitor hybrid energy system in solar car" 8th International Conference on Power Electronics - ECCE Asia May 30-June 3, 2011

[8] S. L. Brunton, C. W. Rowley, S. R. Kulkarni, and C. Clarkson, “Maximum Power Point Tracking for Photovoltaic Optimization using Extremum Seeking”, Princeton University, Princeton.

[9] D. King-Hele, “Erasmus Darwin's Improved Design for Steering Carriages-and Cars”, The Royal Society London, pp. 41–62, 2002.

[10] Dounya Barrit, Yassine Salih-Alj, Symposium on Industrial Electronics and Applications (ISIEA2012), “Solar Powered Car with a Hybrid Backup System”, Bandung, Indonesia, September 23-26, 2012.

[11] Vineeth .V Vincent,S.Kamalakkannan, “Advanced Hybrid System for Solar Car”, 2013International Conference on Computation of Power, Energy.

[12] Gaddy, E. (2003, May). Photovoltaics for hybrid automobiles. In Photovoltaic Energy Conversion, 2003. Proceedings of 3rd World Conference on (Vol. 3, pp. 2827-2832). IEEE.

[13] Beaucarne, G. (2007). Silicon thin-film solar cells. Advances in OptoElectronics, 2007.

[14] Li, W., Varlamov, S., Jung, M., & Huang, J. (2014). Vapour-Phase and Solid-Phase Epitaxy of Silicon on Solid-Phase Crystallised Seed Layers for Solar Cells Application. International Journal of Photoenergy, 2014.

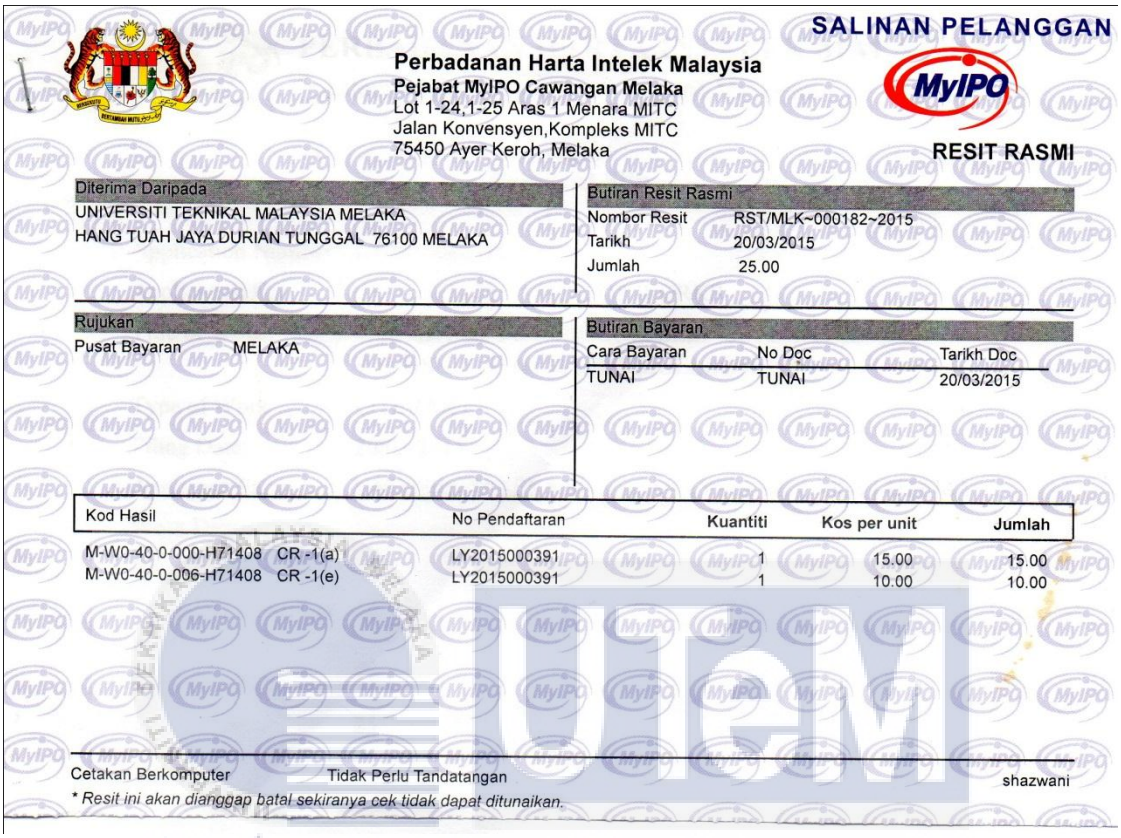
[15] Zeman, M., & Krc, J. (2008). Optical and electrical modeling of thin-film silicon solar cells. Journal of Materials Research, 23(04), 889-898.

[16] Huang, Y., Dasgupta, A., Gordijn, A., Finger, F., & Carius, R. (2007). Highly transparent microcrystalline silicon carbide grown with hot wire chemical vapor deposition as window layers in nip microcrystalline silicon solar cells. Applied physics letters, 90(20), 203502-203502.

[17] Khan, M., & Kockelman, K. M. (2012). Predicting the market potential of plug-in electric vehicles using multiday GPS data. Energy Policy, 46, 225-233.

APPENDIX A

Myipo‟s Patent Customer Copy



SALINAN PELANGGAN

Perbadanan Harta Intelek Malaysia
Pejabat MyIPO Cawangan Melaka
Lot 1-24,1-25 Aras 1 Menara MITC
Jalan Konvensyen,Kompleks MITC
75450 Ayer Keroh, Melaka

RESIT RASMI

Diterima Daripada
UNIVERSITI TEKNIKAL MALAYSIA MELAKA
HANG TUAH JAYA DURIAN TUNGGAL 76100 MELAKA

Butiran Resit Rasmi
Nombor Resit RST/MLK~000182~2015
Tarikh 20/03/2015
Jumlah 25.00

Rujukan
Pusat Bayaran MELAKA

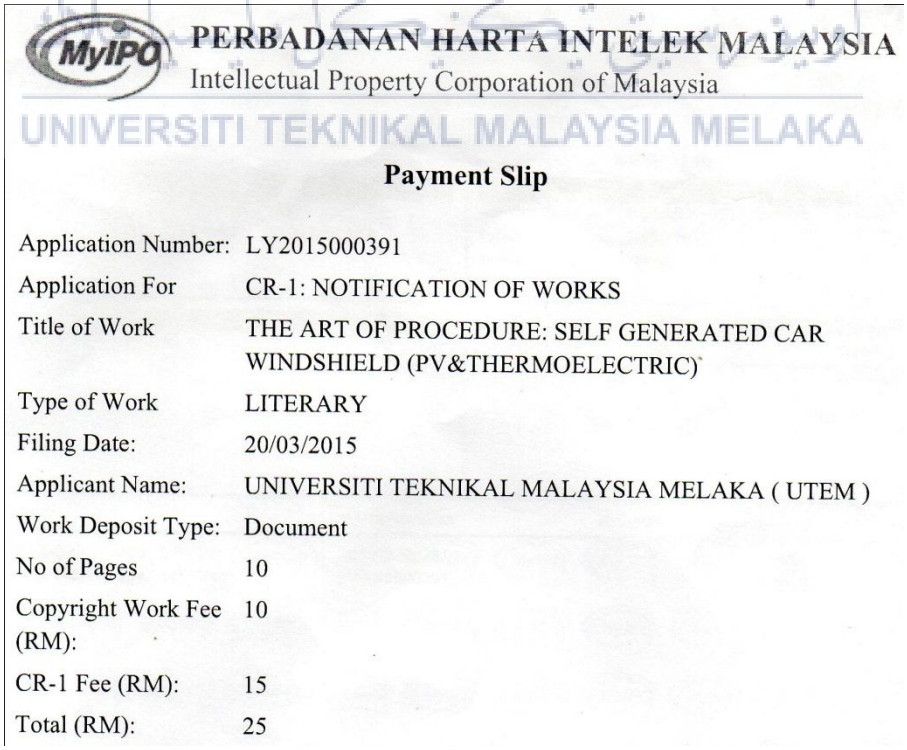
Butiran Bayaran

Cara Bayaran	No Doc	Tarikh Doc
TUNAI	TUNAI	20/03/2015

Kod Hasil	No Pendaftaran	Kuantiti	Kos per unit	Jumlah
M-W0-40-0-000-H71408 CR -1(a)	LY2015000391	1	15.00	15.00
M-W0-40-0-006-H71408 CR -1(e)	LY2015000391	1	10.00	10.00

Cetakan Berkomputer Tidak Perlu Tandatangan shazwani

** Resit ini akan dianggap batal sekiranya cek tidak dapat ditunaikan.*



PERBADANAN HARTA INTELEK MALAYSIA
Intellectual Property Corporation of Malaysia

Payment Slip

Application Number:	LY2015000391
Application For	CR-1: NOTIFICATION OF WORKS
Title of Work	THE ART OF PROCEDURE: SELF GENERATED CAR WINDSHIELD (PV&THERMOELECTRIC)
Type of Work	LITERARY
Filing Date:	20/03/2015
Applicant Name:	UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM)
Work Deposit Type:	Document
No of Pages	10
Copyright Work Fee (RM):	10
CR-1 Fee (RM):	15
Total (RM):	25

APPENDIX B

Certificate of Participation in iCompex‟15

APPENDIX C

Certificate of Participation in iEnvex2015

APPENDIX D

Poster of iCompex‟15 Exhibition

APPENDIX E

Poster of iEnvex2015 Exhibition

APPENDIX F

Poster of Infineon Week Competition