DEVELOPMENT OF SOLAR BASED BATTERY CHARGING SYSTEM FOR ELECTRIC CARS

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By

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FINAL REPORT

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CERTIFICATION OF APPROVAL

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June 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Mohd Khairul Faqih bin Mohd Khir

ABSTRACT

The main aim of this project is to develop a battery charging system for electric cars using solar energy from the sun. The increasing demand and decreasing availability of natural energy sources, has triggered the alarm for the need of these type of energy to be conserved. In the transportation sector, problems caused by the internal combustion engine vehicles (ICEV) are becoming a highlighted issue. Gas emissions from this type of vehicles are harmful to the environment and contribute to the global warming. This project focuses on the development of electric vehicles battery charging system. Electric vehicles are not absolutely gas emission free and still consume derivatives of petroleum and natural gas indirectly by using electricity from the grid to charge its battery. Instead of using the electricity from the grid, which is produced by generators in power plant stations that consumes petroleum and natural gas, the electric car is charged through a system that harnesses electricity from the sun's radiation. The results from this project show that it is possible and feasible to charge the battery of the electric car using a solar based battery charging system.

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It has definitely been a great and eye-opening new experience that will help me to improve my qualities as a future engineer and build my character to face the problems and issues of tomorrow.

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LIST OF ABBREVIATIONS

AC	Alternating Current
BEV	Battery Electric Vehicle
DC	Direct Current
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
ICEV	Internal Combustion Engine Vehicle

CHAPTER 1
INTRODUCTION

1.1 Background of study

The issue of conserving energy is becoming very important. With the increasing demand for natural energy sources such as natural gas and crude oil, alternative sources for energy is being searched to minimize the usage of these non-renewable energy. The major consumers of these natural sources are the electric power generation and transportation sector. The number of vehicles on the road is increasing rapidly along with the development of technology. The improving lifestyles and economy stability as well as the decreasing price of vehicles in the market have made vehicles even more affordable to the consumers. In Malaysia, almost every house in the country has more than one vehicle. The recent car rebate program by the government is a step to get the old cars out of the road and reduce the number of cars. [9]

Most of the vehicles on the road are conventional vehicles which use internal combustion engine (ICE). This type of engine uses petrol and diesel as its fuel. Concerns have been raised due to the effects of using this engine which causes environmental and health problems. The increasing number of these vehicles on the road makes the situation worse [9].

Various major automobile companies such as Honda and Toyota have turned their focus on electric vehicles and they have been developing electric and hybrid vehicles to solve the problem caused by the ICE vehicles. Honda has come up with their Honda Civic Hybrid [11] and Toyota has released Toyota Prius [12], which are hybrid cars. But, although these types of cars reduce the consumption of fuel, it does not completely eliminate it. The hybrid combines the ICE and electric from battery to move, while although the electric vehicles completely gets its power from the on-board battery, fuel is still consumed when the electric vehicles is charged through the electrical power grid.

1.2 Problem Statement

The transportation sector is one of the major consumers of natural energy. The ICE vehicles use petroleum or diesel as its fuel. With the increasing number of these type of vehicles, the demand for petroleum and diesel also increases. Since they are non-renewable type of energy source, the supply will eventually run out if its consumption is not controlled.

The ICE produces and releases harmful gases such as carbon monoxide, hydrocarbons, and oxides of nitrogen into the atmosphere through the combustion process in the engine. The effect to the environment are for example, the thinning of the ozone layer, the green house effect, global warming and also contributes to many health hazards to humans.

The price of petrol and diesel are very unstable and always fluctuate in the global market. A recent example, the fuel price hike in Malaysia (July 2007) [10] has reduced the consumer's ability to pay for fuel. This affects the economy since with the rise of fuel price, other commodities prices such as rice, sugar, and flour for example, will also increase.

1.3 Project Objectives

The objectives of this project are :

i) To carry out feasibility studies on the possibility of using solar electricity in an electric car.

ii) To design a solar battery charging system for an electric car.

1.4 Scope of Studies

The scope of study for this project are :

i) ICE Cars, Hybrid Electric Car, and Battery Electric Car.

ii) Solar Radiation, Solar Energy, Solar Power Generation.

CHAPTER 2

LITERATURE REVIEW

2.1 Conventional Vehicles

The conventional vehicle uses internal combustion engine (ICE) to generate force to move its wheel. Force is generated by this engine by the combustion process of fuel (petrol or diesel) with oxygen in the engine's combustion chamber. The expansions of the high temperature and high pressured gases, which are produced by the combustion, will directly apply force to the vehicle's pistons and by moving it over a distance, mechanical energy is generated which moves the wheels of the vehicle [1].

The vehicle also has a rechargeable battery that supplies electric energy to power the starter motor, the lights, and the ignition system of the vehicle's engine. A typical vehicle battery (usually of lead-acid type) provides a nominal 12-volt potential difference by connecting six galvanic cells in series. Lead-acid batteries are made up of plates of lead and separate plates of lead dioxide, which are submerged into an electrolyte solution of about 35% sulfuric acid and 65% water [1]. This causes a chemical reaction that releases electrons, allowing them to flow through conductors to produce electricity. As the battery discharges, the acid of the electrolyte reacts with the materials of the plates, changing their surface to lead sulfate. When the battery is recharged (vehicle's engine-driven alternator powers the vehicle's electrical systems and restores charge used from the battery during engine cranking), the chemical reaction is reversed, and the lead sulfate reforms into lead oxide and lead. With the plates restored to their original condition, the process may now be repeated [1].

The problem with this type of vehicle is that its internal combustion engine releases air pollution emissions through its exhaust, due to incomplete combustion of the engine's fuel. The main derivatives of the process are carbon dioxide CO_2, water and some soot. The effects of inhaling particulate matter have been studied in humans and animals and include asthma, lung cancer, cardiovascular issues, and premature death. There are however some additional products of the combustion process that include nitrogen oxides and sulfur and some uncombusted hydrocarbons, depending on the operating conditions and the fuel-air ratio [1].

Not all of the fuel will be completely consumed by the combustion process; a small amount of fuel will be present after combustion, some of which can react to form oxygenates, such as formaldehyde or acetaldehyde, or hydrocarbons not initially present in the fuel mixture. The primary causes of this is the need to operate near the stoichiometric ratio for gasoline engines in order to achieve combustion and the resulting "quench" of the flame by the relatively cool cylinder walls, otherwise the fuel would burn more completely in excess air. When running at lower speeds, quenching is commonly observed in diesel (compression ignition) engines that run on natural gas. It reduces the efficiency and increases knocking, sometimes causing the engine to stall. Increasing the amount of air in the engine reduces the amount of the first two pollutants, but tends to encourage the oxygen and nitrogen in the air to combine to produce nitrogen oxides (NO_x) that has been demonstrated to be hazardous to both plant and animal health. Further chemicals released are benzene and 1,3-butadiene that are also particularly harmful; and not all of the fuel burns up completely, so carbon monoxide (CO) is also produced. Carbon fuels contain sulfur and impurities that eventually lead to producing sulfur oxides (SO) and sulfur dioxide (SO_2) in the exhaust which promotes acid rain [1].

One final element in exhaust pollution is ozone (O3). This is not emitted directly but made in the air by the action of sunlight on other pollutants to form "ground level ozone", which, unlike the "ozone layer" in the high atmosphere, is regarded as a bad thing if the levels are too high. Ozone is broken down by nitrogen oxides, so one tends to be lower where the other is higher [1].

2.2 Battery Electric Vehicle (BEV)

BEVs use the electrical energy stored in batteries to power the drive or traction motors of the vehicle. BEVs produce zero emissions. The only emissions related to a BEV are those released when coal or natural gas are used in power plants to generate the electrical energy required to charge the battery. BEVs are unable to travel far between battery recharges, due to the limitations of the battery [1].

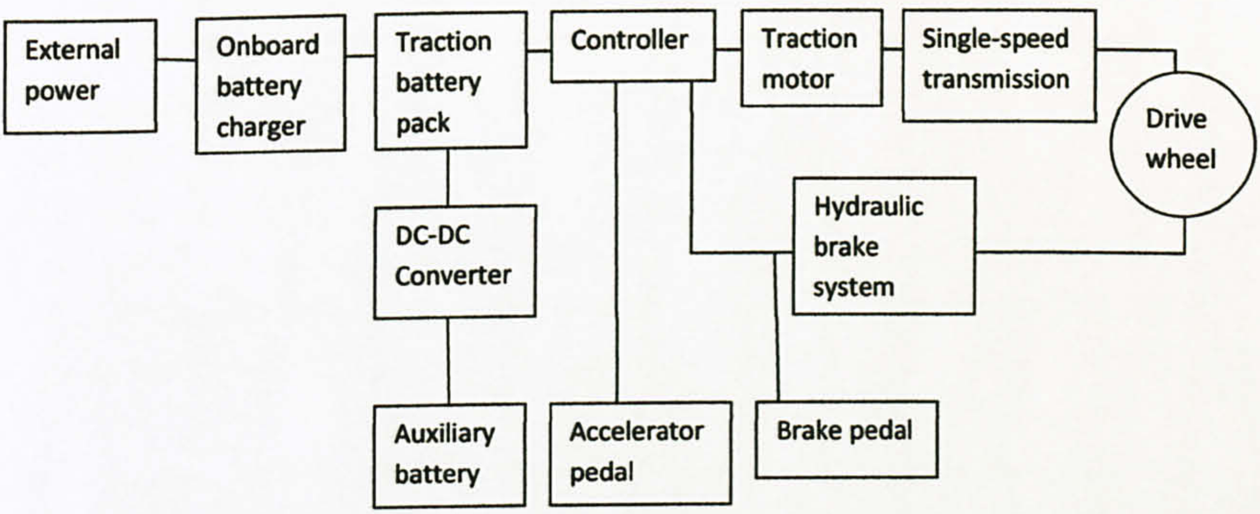

Figure 1 Major components of a BEV [1]

Figure 1 shows the major components of a typical BEV. The drive wheel of a BEV is moved by the traction motor which uses single speed transmission. This motor is controlled by a controller which is powered by the traction battery pack. The input to this controller is the accelerator pedal (to accelerate the BEV), and the brake pedal, which is connected to the hydraulic brake system of the BEV (to de accelerate the BEV). The traction battery pack is charged from an external power (e.g : from electrical grid at home) through the onboard battery charger. The traction battery pack also supplies power to an auxiliary battery which distributes electricity for the BEV's electrical components such as the radio, the head lamps and rear lamps, and also the power window.

2.3 Hybrid Electric Vehicles

Hybrid electric vehicles (HEV) combine the technologies of BEVs and ICEVs. This type of car is designed to take advantage of the positives of both BEVs and ICEVs. Each of them work together to improve the efficiency and performance of each other while at the same time, minimizing the disadvantages of each other. A typical ICEV has more reliable power than it needs for most driving situation. Out of 150 horsepower that most ICEV can produce, only 20 to 40 horsepower are needed to maintain cruising speed. The rest of the power is needed only for accelerating and overcoming loads, such as climbing up a hill. Hybrid vehicles typically use a smaller ICE and the electric motor provides power for accelerating and overcoming loads [1].

Depending on the system used, the engine may power the vehicle by itself, or it may drive a generator, or both. Often, the motor is used as the propulsion unit when the vehicle is travelling at low speeds. As soon as a specific speed or load is passed, the engine will then take over. The hybrid system are categorized into series or parallel type. A series hybrid is never directly powered by the engine. It drives a generator that either charges the battery or directly powers the electric motor that drives the wheels. In a parallel hybrid, the engine, the motor, or both can power the drive wheels and a generator is also drive by the engine to charge the battery. HEVs can have more than 90% fewer emissions than the cleanest conventional vehicles. This is as a result to the use of smaller and more efficient ICEs. The engine's power is boosted by electric motors that produce zero emissions. The engine can be shut down when not needed. But hybrids will never be zero-emissions vehicle, because it relies on an engine for much of its power [1].

2.4 Basic Principles of Photovoltaics (PV)

Sunlight can be converted into electricity using photovoltaics (PV), concentrating solar power (CSP), and various experimental technologies. PV has mainly been used to power small and medium-sized applications, from the calculator powered by a single solar cell to off-grid homes powered by a photovoltaic array. Photovoltaics is the direct conversion of light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current results that can be used as electricity [13].

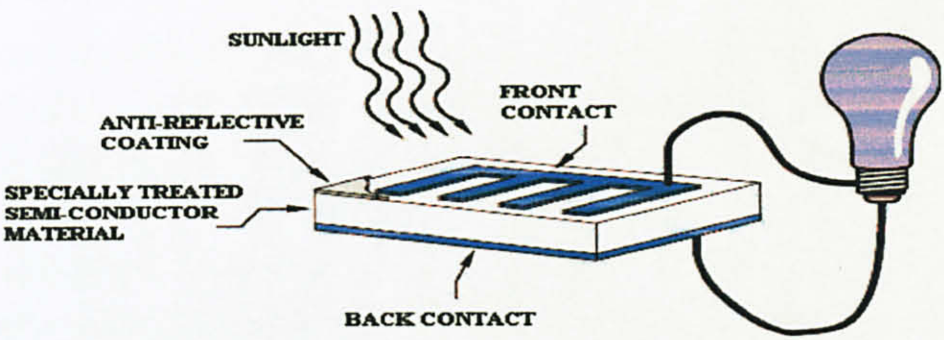

Figure 2 Operation of a basic photovoltaic cell [13]

Figure 2 illustrates the operation of a basic photovoltaic cell, also called a solar cell. Solar cells are made of the same kinds of semiconductor materials, such as silicon, used in the microelectronics industry. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other.

When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current -- that is, electricity. This electricity can then be used to power a load, such as a light or a tool.

2.4.1 Photovoltaic's Efficiency

Most of the energy that reaches a cell in the form of sunlight is lost before it can be converted into electricity. The maximal sunlight-to-electricity conversion efficiencies for solar cells range up to 30% (and even higher for some highly complex cell designs), but typically efficiencies are in the range of 10%-15%. Most current work on solar cells is directed at enhancing efficiency while lowering cost. Efficiency is an important aspect for the application of solar cells. As the solar cell's efficiency increases, the size of the solar cells can be reduced to produce the same power as the one with lower efficiency. [5] Research and development are continuing to overcome these two constraint of using solar energy which are space and cost. The major phenomena that limits cell efficiency are :

i) Reflection from the cell's surface – some of the sunlight that strikes a solar cell is reflected. Normal, untreated silicon reflects 36% of the sunlight that strikes it. Several ways of treating cell surfaces are chemically coating and texturing the surface.
ii) Light that is not energetic enough to separate electrons from their atomic bonds – at an energy tha is specific to the atomic material and its atomic structure, light can free an electron from its bond rather than just cause the bond to vibrate
iii) Light generated electrons and holes (empty bonds) that randomly encounter each other and recombine before they can contribute to cell performance
iv) Self-shading resulting from top-surface electric contacts – refers to losses engendered by the electrical grid on top of the cell, which reflects light that otherwise would enter the cell.

2.4.2 Future of Photovoltaics

The use of solar cells is limited only by the imagination. All the needed technical know-how exists to design PV for application to any system. There are many areas, even today, where PV can be practical and/or cost effective for producing electricity. Considerable work remains to develop a broad range of long-lasting, practical, affordable devices [6].

Utilities conceivably have the option of using PV generated electricity in two ways: for base load or for peaking load. Base-load application at large utilities will require the greatest progress in PV systems development. Primarily, PV systems will be able to compete directly almost everywhere with diesel-engine-generated electricity. A number of experts on PV economics believe that PV's being competitive with diesel-produced electricity will make PV systems suitable for low-to-medium-power electricity generation at utilities dependent on diesel generation. PV will be able to compete at utilities providing peak-load generation – at least in areas where peak loads do not extend into non-daylight hours [6].

2.5 Types of Photovoltaic Modules

A photovoltaic module is an interconnected assembly of photovoltaic cells, also known as solar cells. There are three types of photovoltaic module which are monocrystalline, polycrystalline, and also amorphous silicon. A PV module consists of many PV cells wired in parallel to increase the output current, and in series to increase the output voltage. The module is encapsulated with tempered glass (or some transparent material) on the front surface, and with a protective and waterproof material on the back surface. The edges are sealed for waterproofing, and there is often an aluminium frame holding everything together in a mountable unit. In the back of the module, there is a junction box, or wire leads, for external connections [13].

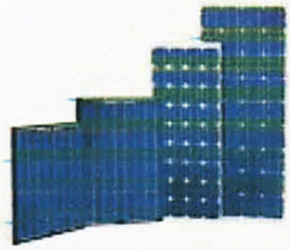

Figure 3 Various sizes of photovoltaic module

2.5.1 Monocrystalline

This type of photovoltaic module is the oldest and has a more expensive production technique compared to the other two types of photovoltaic module, but has the most efficient sunlight to electricity conversion percentage. It has a single and continuous crystal lattice structure with practically zero defects or impurities. The average lifetime of this module is about 25-30 years. These panels typically retail between USD10.00 and USD11.00 per watt [13].

2.5.2 Polycrystalline

Pollycrystalline silicon is a material consisting of multiple small silicon crystals. This module is manufactured with a lower cost compared to the monocrystalline module but has lower lifetime (10-25 years) and lower efficiency. Polycrystaline cells have a bluish color and are usually the same size as monocrystalline cells. These panels typically retail between USD8.50 and USD9.50 per watt [13].

The main advantage of using polycrystalline silicon is that the mobility is far larger than other types of silicon and the material also shows greater stability under electric field and light-induced stress. This allows far more complex, high speed electrical circuits that can e created on the glass substrate along with the amorphous silicon devices, which are needed for their low-leakage characteristics [13].

2.5.3 Amorphous Silicon

Amorphous silicon (a-Si) is a non-crystalline allotropic form of silicon. The cells have a typically uniform black appearance. This silicon material is vaporized and deposited on glass or stainless steel. An amorphous silicon module costs the lowest out of the three type of modules discussed in this chapter with an efficiency of 6% - 8% and a lifetime of up to 10 years. Aside from being low cost, amorphous silicon can be produced at a lower temperature and can be deposited on low cost substrates. These characteristics make amorphous silicon the leading thin film PV material [13].

2.6 Rechargeable Batteries

Rechargeable batteries (Deep Cycle Batteries) are designed to be discharged and re-charged hundreds or thousands of times. These batteries are rated in ampere hours (Ah). Simply stated, ampere hours refers to the amount of current (in ampere) which can be supplied by the battery over a period (in hour). For example, a 350Ah battery could supply 100 ampere of current over a period of 3 and a half hours. To quickly express the total watts potentially available in a 6V 350Ah battery, 350Ah times the nominal 6V equaling to 2100Wh (watt-hour). Similar to solar panels, batteries are connected in series to increase the output voltage and in parallel to increase the output current [15].

Lead-acid batteries are the most common in PV systems because their initial cost is lower and because they are readily available nearly anywhere in the world. There are many different sizes and designs of lead-acid batteries, but the most important characteristic is that they are deep cycle batteries. Lead acid batteries are available in both wet-cell and sealed versions [15].

2.7 Proton Emas

Proton Emas, manufactured by PROTON was unveiled at the 80th Geneva Motor Show in Switzerland on the 2nd of March 2010. It is a concept global car and has three versions which are the EMAS, EMAS Country and EMAS3 [14].

EMAS stands for Eco Mobility Advance Solution, and is a result of the joint collaboration between PROTON and its subsidiary Lotus, and Italian design house, Italdesign Giugiaro(IDG). The EMAS series is a family of low-environmental-impact cars and are expected to revolutionize traditional car market segmentation. It consists of a five-door four seater hatchback 'EMAS' for comfort driving, a three-door five-seater hatchback 'EMAS country' for country driving, and a three-door 3+1 plus-seater 'EMAS3' for city driving [14].

The cars are powered by a serial hybrid plug-in drive system developed by Lotus Engineering that includes a 3-cylinder 1.2 litre internal combustion engine developing 51 horsepower (38 kW) at 3500 rpm [8]. The engine is able to run on petrol, ethanol, methanol or natural gas. Other specifications for this car are :

Length (mm)	: 3555-3000
Height (mm)	: 1576
Width (mm)	: 1699
Electric motor position	: rear
Power	: 75kW (peak), 45kW (continuous)
Maximum torque	: 240Nm
Batteries	: 100 x 31 Ah Cells, 370 Volts, 11.47kWh
Time for full recharge	: 3 hours with normal 240 Volt, 13A power
Range in electric mode	: 50km
Top speed	: 170km/h (peak), 130km/h (continuous)
One-speed gearbox	: final drive ratio 4.214:1

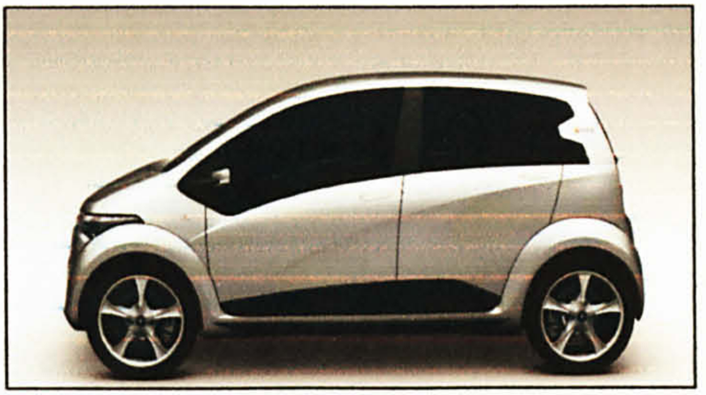

Figure 4 Proton EMAS [8]

Figure 5 Inside look of Proton EMAS [8]

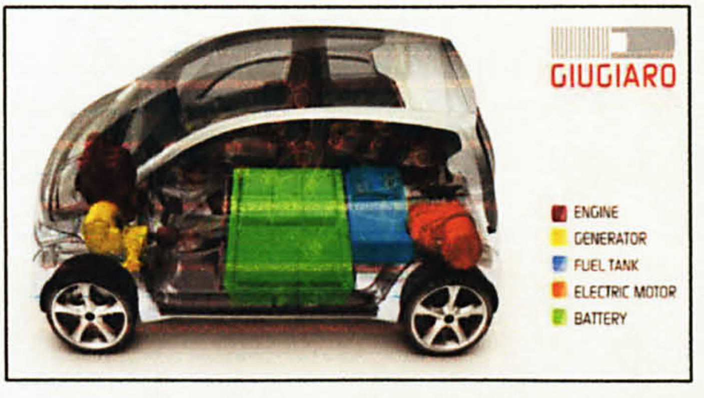

Figure 6 Layout of important mechanicals in Proton EMAS [8]

2.8 Solar Geometry

With the objective to maximize the use of the radiation energy from the sun, it is very important to understand the concept of solar geometry. By learning the concept of solar geometry, we can gain understanding about the solar movement and methods to maximize the solar radiation absorption by the photovoltaic. Ideally, to get maximum radiation conversion from the sun, the angle between the photovoltaic surface and the sun's beam must be perpendicular. In other words, the photovoltaic surface must face directly to the sun as in Figure 3 below.

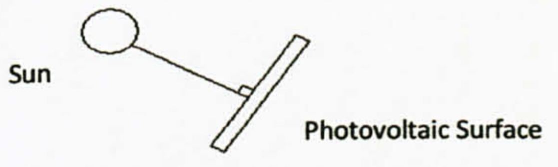

Figure 7 Perpendicular angle between sun and photovoltaic surface

The beam radiation is the solar radiation received from the sun without having been scattered by the atmosphere. The other source of extraterrestrial radiation is the diffuse radiation, which is the solar radiation received from the sun after its direction has been changed by scattering by the atmosphere. Both of these types of radiations sums up to the total solar radiation received on a surface [3].

CHAPTER 3
METHODOLOGY

3.1 Flowchart

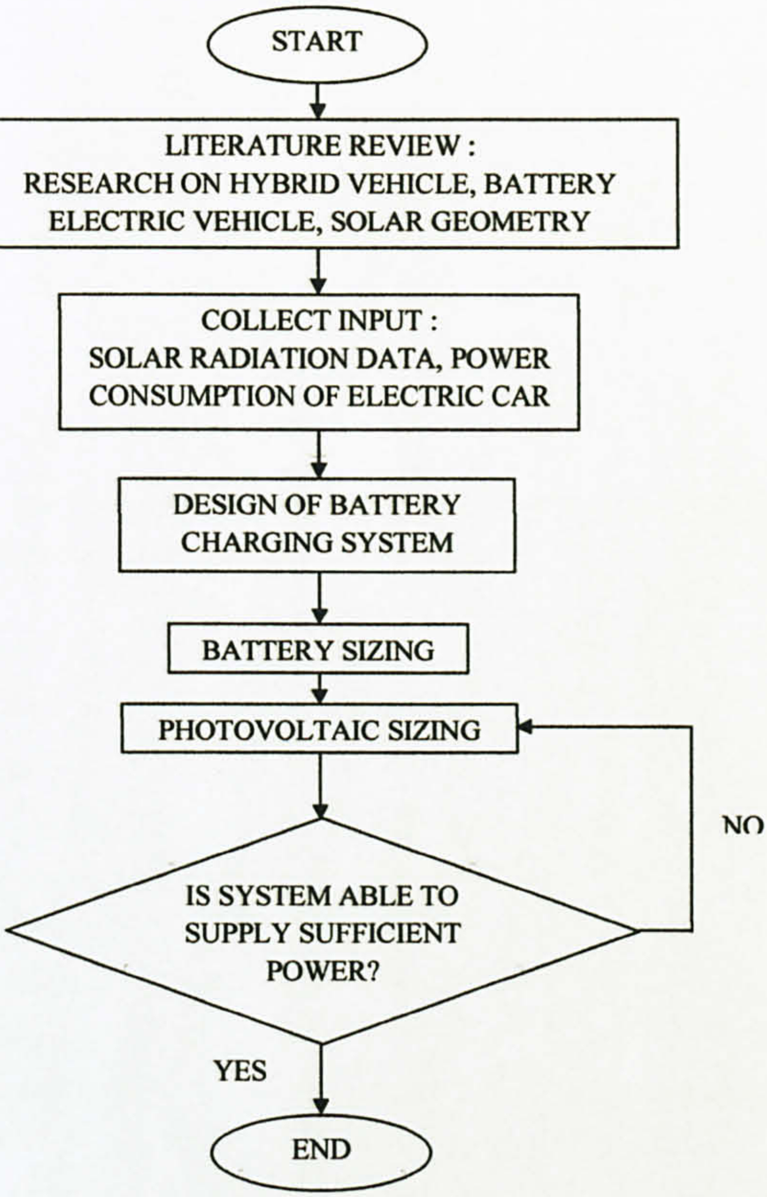

Figure 8 Project flowchart

The first step taken for this project is to do literature reviews and researches on conventional vehicles, hybrid vehicles, battery electric vehicles, solar geometry, basic principles of photovoltaic, types of photovoltaic, and batteries. An efficient literature review is important to ensure that concepts which are essential to this project are well understood and basic principles are covered.

After sufficient research is done, necessary data is collected as inputs for the designing stage. For this project, there are two important inputs which are the daily solar radiation data and also the power consumed by an electric car. For daily solar radiation data, data is collected from the Solar Insulation Measuring Device located in solar laboratory, Universiti Teknologi PETRONAS. For the power consumption by an electric car, Proton Emas's specifications are used as inputs to calculate and size the battery charging system's component, mainly the battery bank and the photovoltaic.

3.2 Tools

The tools that are used in completing this project can be categorized into hardware and software tools as listed below.

3.2.1 Hardware

i) Photovoltaics
ii) Solar Insulation Measuring Device – tracks the movement of the sun for maximum radiation, store daily data of solar radiation
iii) Digital Multimeter – to measure voltage, current
iv) 12V Rechargeable Lead Acid Battery
v) 6V Rechargeable Lead Acid Battery
vi) Solar Charge Controller – control the charging process, act as a regulator
vii) Wooden board – basic material in making the solar station model
viii) Remote Control Car

3.2.2 Software

i) Microsoft Office Word – for documentation (report writing) purposes.

ii) Microsoft Office PowerPoint – slide presentation for seminar and oral presentation.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Data Collection

Necessary data is needed to determine whether this project is feasible and as inputs for the designing stage. For this project, there are two important inputs which are the daily solar radiation data and also the power consumed by an electric car.

4.1.1 Solar Radiation Data

This data is taken from Universiti Teknologi PETRONAS's solar laboratory. The data is measured by the Solar Insulation Measuring Device.

Figure 9 Solar Insulation Measuring Device

This device, placed on top of a tower near the solar laboratory, tracks the movement of the sun to get the maximum solar radiation value. This device can move along the x, y, and z axis and its movement is controlled by a motor. The solar radiation is measured by the piranometer attached on top of the device.

Table 1 Daily Solar Radiation Data

DATE	TIME	SOLAR GLOBAL RADIATION (W/m^2)
24/1/2010	07.00 am	0.00
24/1/2010	07.30 am	5.40
24/1/2010	08.00 am	65.50
24/1/2010	08.30 am	168.82
24/1/2010	09.00 am	195.84
24/1/2010	09.30 am	214.07
24/1/2010	10.00 am	515.93
24/1/2010	10.30 am	602.03
24/1/2010	11.00 am	710.75
24/1/2010	11.30 am	805.30
24/1/2010	12.00 pm	1017.00
24/1/2010	12.30 pm	1012.61
24/1/2010	01.00 pm	1111.54
24/1/2010	01.30 pm	1028.82
24/1/2010	02.00 pm	752.62
24/1/2010	02.30 pm	913.01
24/1/2010	03.00 pm	946.43
24/1/2010	03.30 pm	1042.33
24/1/2010	04.00 pm	203.94
24/1/2010	04.30 pm	11.82
24/1/2010	05.00 pm	16.88
24/1/2010	05.30 pm	16.21
24/1/2010	06.00 pm	15.53
24/1/2010	06.30 pm	14.18
24/1/2010	07.00 pm	10.13

Based on the tabulated data above, the peak solar radiation is 1111.54 W/m^2, registered at 1.00pm. Higher values of solar radiation (above 500 W/m^2) are registered from 10.00am to 4.00pm. This gives a total of 6 hours of high solar radiation value available daily and supports the feasibility of using solar radiation energy. Because Malaysia is located near Earth's equator, our country enjoys long duration of sunshine and with the availability of long hours of high solar radiation value, solar energy is very practical and possible to harness.

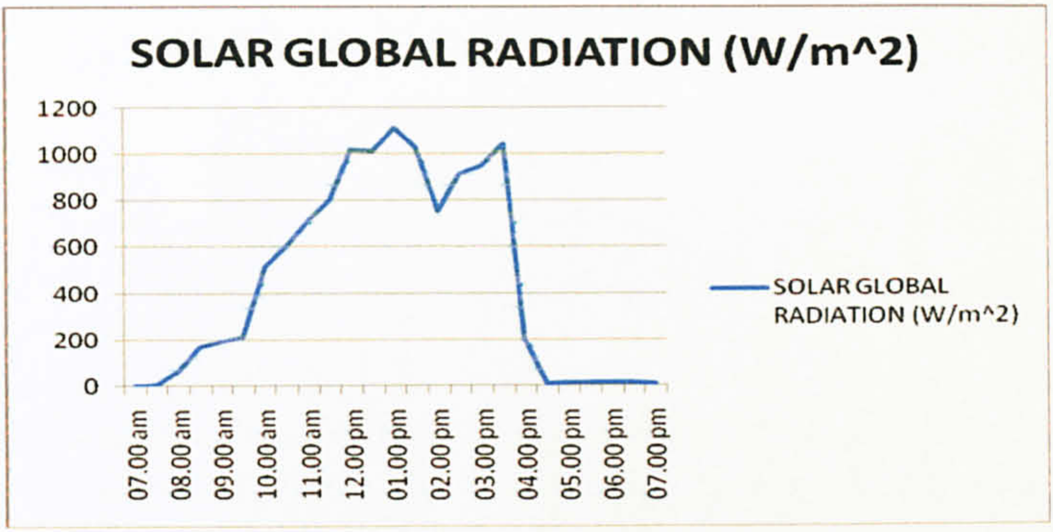

Figure 10 Graph of Daily Solar Radiation Based on Table 1

Based on the graph above, the solar radiation has a transient nature and varies with time. Because of this fluctuating property, it is not suitable and reliable to use solar energy for practical application. Cloudy days and rain can also affect the solar radiation value. To overcome this problem, it is essential to store the energy from the solar radiation in a storage system before being used. This can also cater for the demand of energy at night, when sunlight is not available.

4.1.2 Power Consumption of an Electric Car

For this project, Proton EMAS hybrid electrical concept car is taken as a case study and the battery charging system will be designed based on this car. Proton EMAS runs on an electric motor which consumes 75kW of power at peak and 45kW at continuous. The batteries that is used to power this motor is an array of 100 x 31 Ah cells, 370 Volts and 11.47kW. To power an electric car by using photovoltaic is not possible since it would be impossible to put a photovoltaic module that can supply enough power to the electric car on the electric car itself. A monocrystalline photovoltaic of 0.15m^2 can generate a maximum of 20W/h. To power the Proton EMAS continuously, it would take a photovoltaic module of 337.5m^2.

4.2 Design of Battery Charging System

This system will have supply power from two sources. The power from solar radiation, which will be stored in a battery bank will act as the main source while electrical power from the grid will be used as the auxiliary or back-up power. Auxiliary power is needed in case the battery bank is empty and is not able to provide sufficient power to charge the electric car. The auxiliary power will also be used if maintenance is needed for the main supply. A charge controller is needed to regulate the voltage from the PV to the battery bank. The charge controller is also needed to control the charging process of the battery bank.

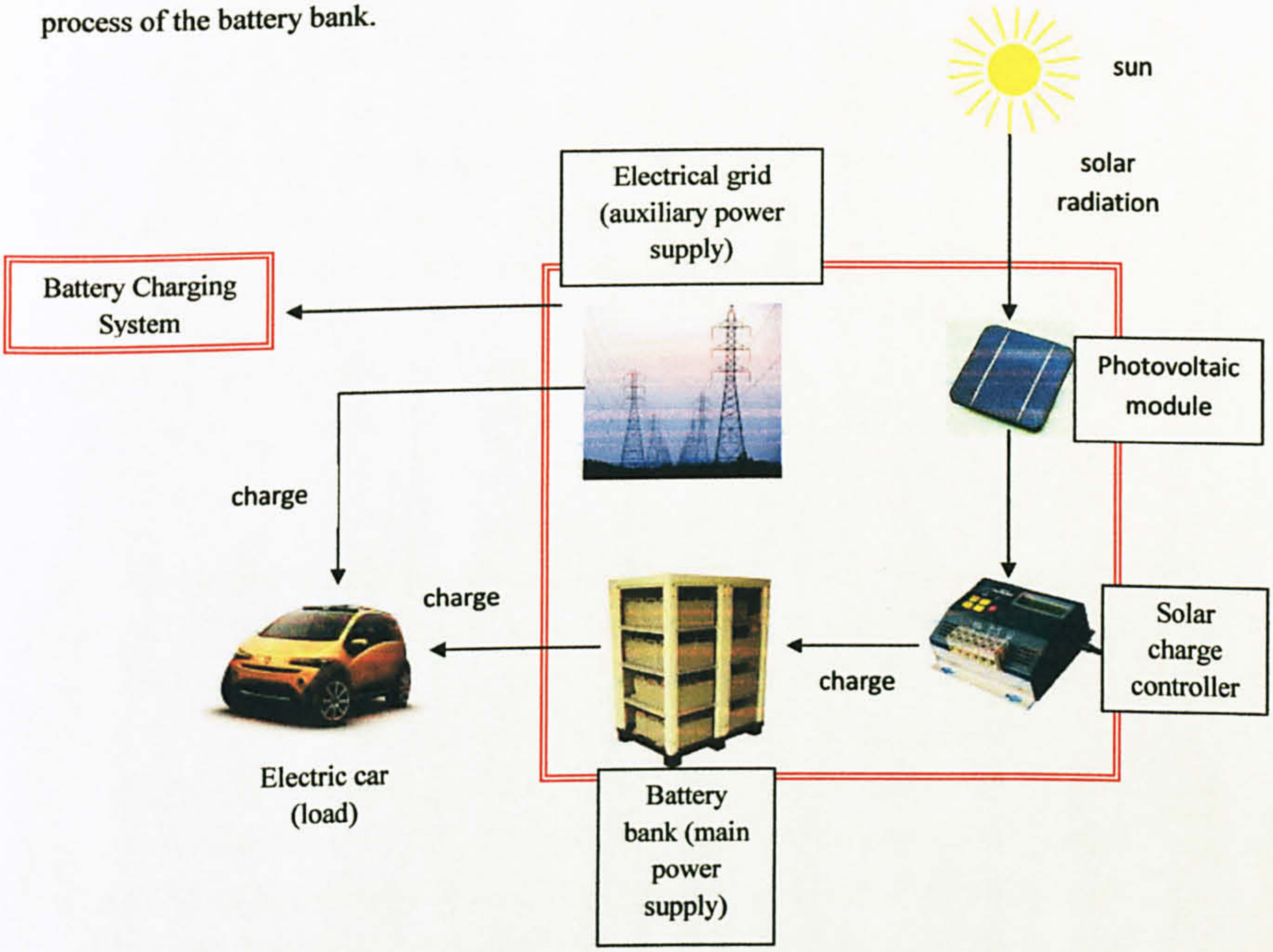

Figure 11 Overall design of battery charging system

4.3 Calculations

4.3.1 Battery Bank Sizing

Proton EMAS runs on an electric motor which consumes 75kW of power at peak and 45kW at continuous. The batteries that is used to power this motor is an array of 100 x 31 Ah cells, 370 Volts and 11.47kW. To be able to charge the battery of this car, the battery bank must have voltage rating more than 370 Volts and power rating more than 11.47kW.

Before the number of batteries and the arrangement of the batteries can be determined, the type of battery must first be chosen. For the application of this charging system, the type of battery that will be used is sealed lead-acid battery with ratings of 12 Volts and 100 Ah [16]. The reason for the choosing of this battery is because this battery is reliable (often used for UPS systems) and has a high rating of ampere hours.

To supply 370 Volts, the number of batteries that must be used;

$$\frac{370V}{12V} = 30.83$$

The number of batteries connected in series will be 35 and the total voltage will equal to 420 Volts.

$$35 \times 12V = 420V$$

The rating of the battery bank is now 420V, 100Ah and has power rating of 42kWh. For the purpose of charging more than one of this car, two of these battery banks will be connected in parallel to boost the current rating, so that the battery bank will last longer and able to charge more than one car simultaneously. The arrangement of the battery bank is shown in Figure 12.

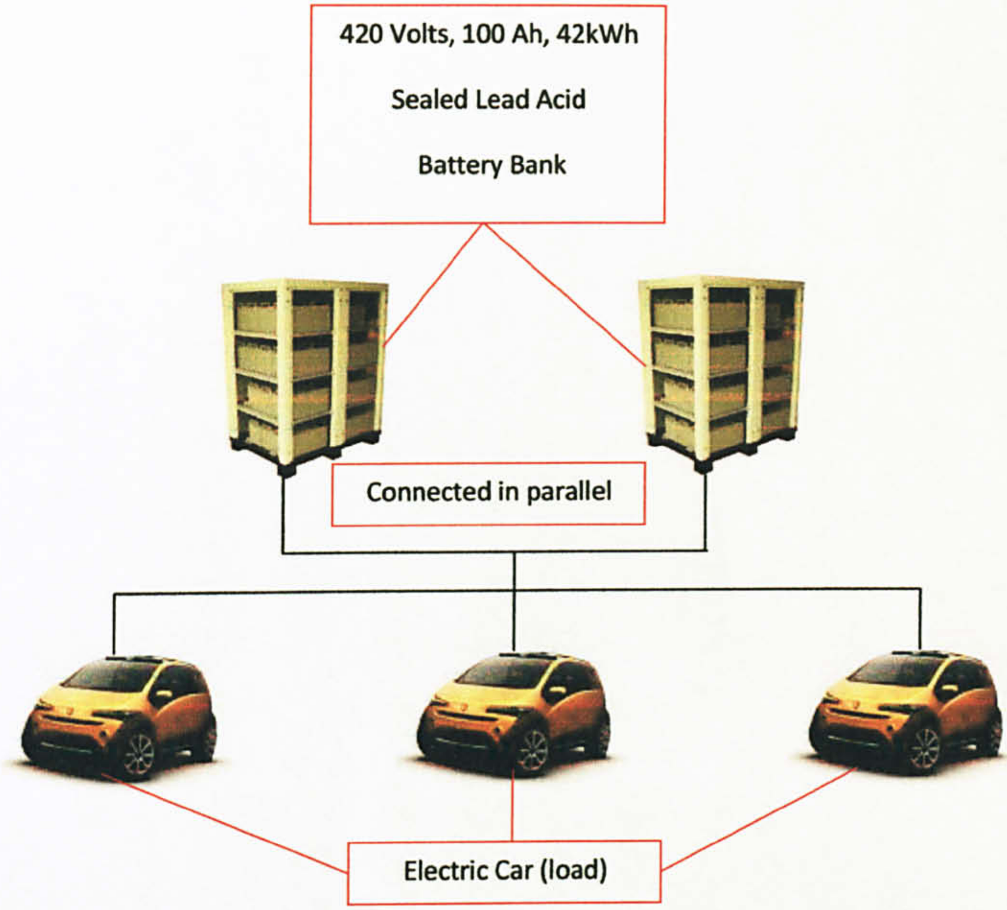

Figure 12 Arrangement of the battery banks

4.3.2 Photovoltaic Sizing

The photovoltaic sizing will be done in reference to the battery bank as the photovoltaic will be used to charge the battery bank. The important parameter here is that the voltage of the photovoltaic and the power rating must be greater than the ratings of the battery bank.

For the photovoltaic sizing, calculations are done based on the polycrystalline photovoltaic module that is bought. Measurements are made to determine the ratings of the photovoltaic. The ratings are as follows; 20W maximum power, 17.28V and 1.16A of rated voltage and rated current. The short circuit characteristics of the photovoltaic module are 21.42V and 1.31A respectively. The dimensions of the module is 0.27m x 0.5m which equals to 0.135m^2 of area.

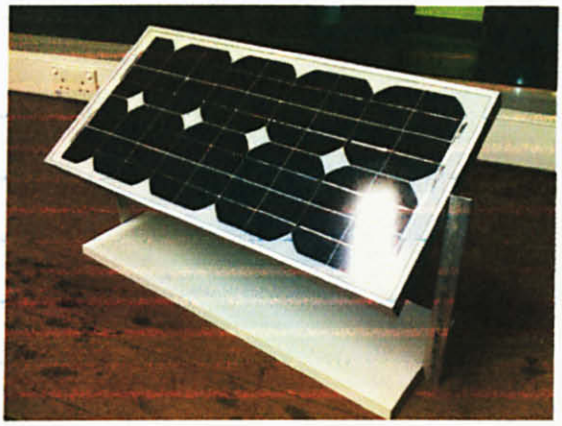

Figure 13 Polycrystalline photovoltaic module

Figure 14 Taking measurements to determine the ratings of the photovoltaic module

The number of photovoltaics that must be connected in series ;

$$\frac{42kW}{20W} = 2100$$

It is better to increase the number of photovoltaics than the value above because the photovoltaic will not always able to produce maximum power. So, the number of photovoltaic connected in series chosen is 2250, resulting in 45kWh maximum power and 47.25kV maximum voltage.

Because of the value of the voltage is very high, the solar charge controller will regulate the voltage to 450V to charge the battery bank.

To charge a battery bank, the photovoltaic would take space of $0.135m^2$ x 2250, which equals to $303.75m^2$ of area.

4.4 Finished Design of Battery Charging System

The finished design of this system would be as in the diagram below :

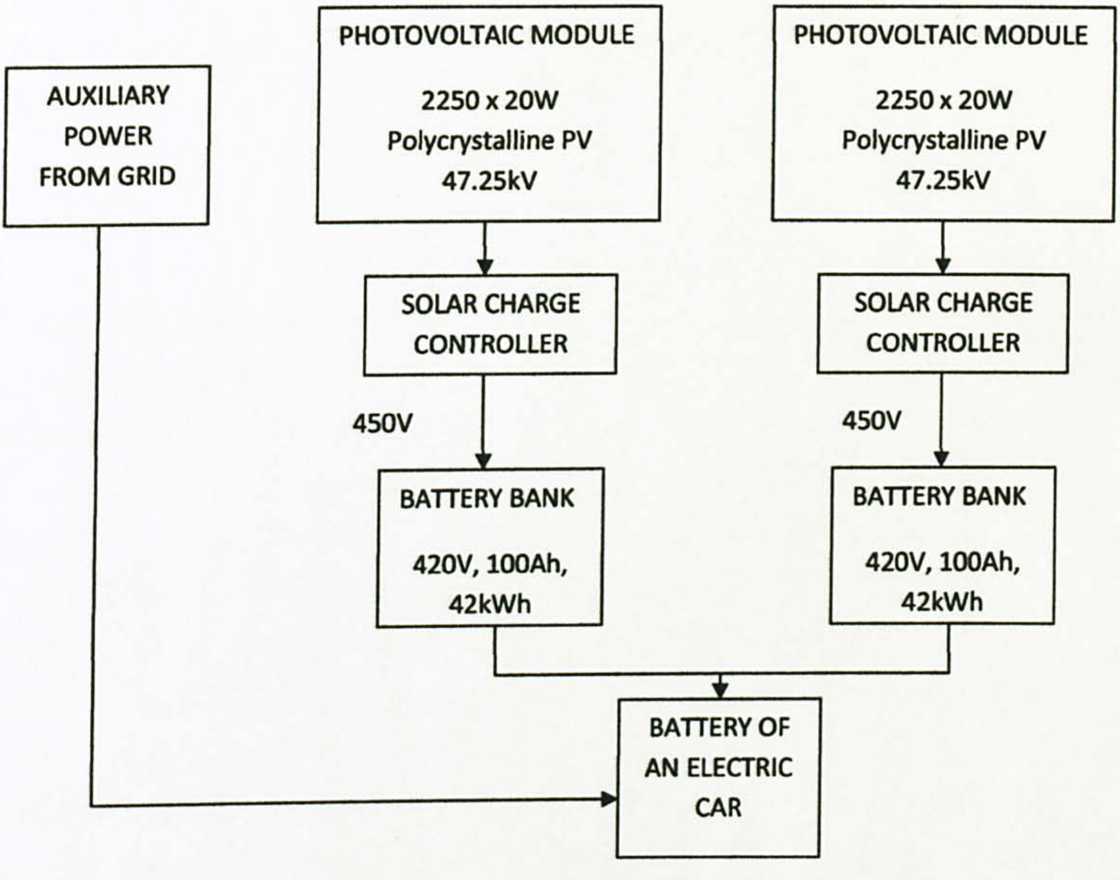

Figure 15 Finished design of battery charging system

4.5 Solar Station Concept

The solar station concept is similar to the concept of refueling the ICEV with petrol or diesel at the gas station. The difference is, instead of refueling gas, the BEV can charge its on-board battery at this station. But, because of the long charging time, it is not practical for the user to wait at the station while their vehicle is recharging. This concept is not suitable to be used in highways. But in the city, or in a neighborhood area, this concept is practical. The user will have to have two batteries. When one of them needs to be recharged, the user will leave the battery at the solar station. The user will then use the other battery which is already fully charged. The user will then collect the battery that is left to be recharged at the solar station sometime later, the following day for example.

4.5.1 Advantages of Solar Station

First of all, it is not suitable to use solar based energy to move an electrical car. A solar module of $1.5m^2$ can generate a maximum of 20 Watts of power. So, there is no possibility for a solar module to be used to power the motor of an electric car which consumes 5 – 10kW of power, as there will not be enough space.

Furthermore, putting a solar module on a car is not efficient as the car moves around and there is high possibility that the car will be shaded by its surroundings such as buildings, or trees, thus preventing the radiation from the sun to hit the solar module.

And it is also not suitable to put this battery charging system at home because it takes a lot of space. It is better to have a solar station in a designated area and can be used by the whole nearby population. Space is conserved in an abundant.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

It is very important to reduce the fossil fuel consumption by the conventional ICE cars, HEV and BEV. One of the solutions is as suggested, a solar station as electrical supply to charge the battery of BEV. Using this system, the usage of fossil fuel will be eliminated, and the objectives of this project will be fulfilled. If this system works and implemented globally, the gas emissions from BEV can be reduced to zero emission. And with the development of electric cars, eventually, it will be the future choice to the road users.

It is not suitable to use solar energy to power an electric car. With current technology, there is not enough space for solar panels that is able to power the motor of an electric car to be put on the electric car.

This system is highly influenced by the development of battery and photovoltaic technology. With the improvement in the battery of the electric car, the charging time can be greatly reduced thus improving the practicality of the system. While more efficient photovoltaic will reduce the area of the photovoltaic used and its price reduction will make the system economically more attractive, and the development of electric car industry will increase the number of users of electric car and these people will want an efficient, cost saving and environmental-friendly way to charge their electric car.

5.2 Recommendations

The reliability of this system can be improved by integrating this system with wind turbine generators. Though wind power is not enough to act as auxiliary power, but by integrating it to the system, it can help to increase the battery charging rate and improve the system's efficiency at the same time.

Maintenance should also be done regularly to ensure that the performance of the photovoltaic does not decline.

The system can have another set of battery bank, connected in parallel so that this second battery bank can act as a backup supply when the first battery bank is dried up of power. With this, the system's reliability can be increased.

A controlling and monitoring system should be designed and installed to the battery charging system. This can help to monitor the battery bank's condition and also the charging process. Maintenance process will be more efficient and costs can be saved.

The voltage that is not used (47.25kV step down to 450V), can be used for other applications, for example, this voltage can be supplied to domestic houses for domestic use.

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APPENDICES

APPENDIX A

GANTT CHART

Details / Week	Semester 1														Semester 2														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Selection of project title/ supervisor	■		H1N1 HOLIDAY						MIDSEM BREAK													MIDSEM BREAK							
Preliminary research • Solar radiation • Solar geometry		■		■																									
Research on solar energy and photovoltaic				■	■																								
Submission of Prelim Report				■																									
Research on conventional vehicle, battery electric vehicle and hybrid vehicle						■	■																						
Submission of progress report								■																					
Project work								■		■	■	■	■																
Seminar											■																		
Submission of final interim report														■															
Oral Presentation														■															
Experiment at Tronoh for solar radiation data															■														
Feasibility study using actual data																■													
Designof battery charging system • Battery sizing • PV sizing																	■	■	■	■	■								
Submission of progress report																					■								
Prototype construction and development																							■	■	■				
Poster exhibition																										■			
Draft report submission																											■		
Submission of dissertation (Soft bound)																												■	
Final presentation																													■
Submission of dissertation (Hard bound)																													■