Faculty of Electrical Engineering

GREEN ENERGY MANAGEMENT SYSTEM (GreEMys)

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GREEN ENERGY MANAGEMENT SYSTEM (GreEMys)

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2014

DECLARATION

I declare that this thesis entitled “Green Energy Management System” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Student Name :...

Date :...

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electrical Engineering (Power Electronic and Drive).

Signature :...

Supervisor Name :...

Date :...

DEDICATION

Specially dedicated to my family.

ABSTRACT

Tenaga Nasional Berhad (TNB) generates, transmits, distributes and sells the energy to consumer throughout Malaysia. With the global environment pollution and energy crisis, a renewable energy is playing a more and more important role in energy production. Solar energy is as a type of renewable energy. It is widely applied in manufacturing and living activities and the battery is the most common of energy storage for the solar system. Commonly, the system is already provided such Uninterruptible Power Supply (UPS) which is used as a backup power supplies while the utility system is out of stage. The battery bank from UPS is charge from the utility power supply and this system will increase the electricity bill. Nowadays, alternative way for reduce electricity bill is by using Renewable Energy (RE) such as solar energy. RE can be store into battery as a backup or it is also can used directly to the appliances. When using a multi power source, which one of the power source to be used first for optimal savings. Therefore, one system are need to make RE is first priority resource for the house and TNB are used after the battery is running out. The Green Energy Management System (GreEMys) is developed to manage the power supplies for house while the house owner used RE and TNB as a power supply. GreEMys will select either one power supply depend on the State of Charge (SOC) of battery. Through this system, while battery stored energy from GE until full, this system will choose RE for supply electricity to house and used until battery is weak, then the system will change to TNB for feed electricity to the house while waiting for the battery recharged by GE again until full. Moreover, this GreEMys can display the mode of power source either RE or TNB and also display the percentage of SOC. Through this system, GreEMys product increase electricity conservation by using solar energy at house as a priority used and TNB are used while RE from battery is exhausted.

ABSTRAK

Tenaga Nasional Berhad (TNB) menjana, menghantar , mengedar dan menjual tenaga kepada pengguna di seluruh Malaysia. Dengan pencemaran alam sekitar global dan krisis tenaga, tenaga yang boleh diperbaharui memainkan peranan yang semakin penting dalam pengeluaran tenaga. Tenaga solar adalah sebagai sejenis tenaga boleh diperbaharui. Ia digunakan secara meluas dalam aktiviti perkilangan dan hidup dan bateri adalah yang paling biasa penyimpanan tenaga untuk sistem solar. Biasanya, sistem sedia ada seperti tidak terganggu Bekalan Kuasa (UPS) yang digunakan sebagai bekalan kuasa sandaran sementara bekalan elektrik terputus. Bank bateri dari UPS akan dicaj daripada bekalan kuasa utiliti dan sistem ini akan meningkatkan bil elektrik. Pada masa kini, cara alternatif untuk mengurangkan bil elektrik adalah dengan menggunakan Tenaga Boleh Diperbaharui (RE) seperti tenaga solar. RE boleh menyimpan tenaga dalam bateri sebagai sandaran atau ia juga boleh digunakan terus kepada peralatan. Apabila menggunakan sumber kuasa yang berbagai, yang salah satu sumber kuasa yang akan digunakan yang perlu memberi keutamaan bagi penjimatan optimum. Oleh itu, satu sistem yang perlu membuat adalah menberikeutamaan kepada RE untuk rumah dan TNB digunakan selepas bateri kehabisan. Sistem Pengurusan Tenaga Hijau (GreEMys) dibangunkan untuk menguruskan bekalan kuasa untuk rumah apabila pemilik rumah menggunakan RE dan TNB sebagai bekalan kuasa . GreEMys akan memilih salah satu bekalan kuasa bergantung *State of Charge* (SOC) bateri. Melalui sistem ini , bateri menyimpan tenaga dari GE sehingga penuh , sistem ini akan memilih RE untuk bekalan elektrik ke rumah dan digunakan sehingga bateri lemah, maka sistem akan berubah kepada TNB untuk rumah sementara menunggu bateri dicaj semula oleh GE lagi sehingga penuh. Selain itu, GreEMys ini boleh memaparkan mode sumber kuasa sama ada RE atau TNB dan juga memaparkan peratusan SOC. Melalui sistem ini, GreEMys peningkatan produk pemuliharaan elektrik dengan memberi keutaman kepada tenaga solar untuk rumah dan TNB digunakan ketika kehabisan tenaga dari batteri.

ACKNOWLEDGMENTS

First and foremost, thanks to Allah for giving me this healthy body that enables me to devoted to the community as well as gaining new knowledge, experience and able to finish this report in the frame of time. Nothing can be done except with the permission of Allah.

I would also like to express my deepest appreciation to all who involved in this Final Year Project especially to my supervisor Dr. Abdul Rahim bin Abdullah and my co-supervisor Encik Hazriq Izzuan bin Jaafar. I am highly indebted to Universiti Teknikal Malaysia Melaka for giving me the opportunities to pursue my Bachelor in Electrical Engineering (Power Electronic and drive)

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CHAPTER 1

INTRODUCTION

1.1 Project Background

There are many reasons why people are now using Renewable Energy (RE) due to inexhaustible and pollution free renewable energy sources. For instance, solar energy attributes high durability and need no fuel. It is able to operate for lengthened period without maintenance. Therefore, solar energy is the best RE until now. The development and the use of RE have drawn extensive attention of the society. Thus, RE will be an additional source for recover the electricity usage in the home to reduce the electricity bill. Solar energy has far been considered the most easily and viable option. These make it economical for all types of applications of remote area.

1.2 Problem Statements

Currently, TNB is the primary resources for utilities. Rising energy prices and growing environment concerns are making RE system more attractive to society. Nowadays, the system are provided is as a backup power system for houses and industry such as Uninterruptible Power Supply (UPS) system. UPS systems might be used to provide uninterrupted, reliable, and high quality power for these sensitive loads. UPS provides backup power circuitry to supply vital systems when a power outage occurs. There is much type of UPS such as standby UPS is known as off-line UPS. It consists of an AC/DC converter, a battery bank, a DC/AC inverter, and a static switch. A passive low pass filter may also be used at the output of the UPS or inverter to remove the switching frequency from the output voltage.

Moreover, Online UPS also contains of converter, battery, inverter and fast static switch. Power to load is catered through conveter-inveter connection. Hence, converter should have capability to charging battery and supply load. This type of UPS is connected in series to load. Thus, this system is not the way for reduce power usage inside building but it will increase the bill that to be paid. Therefore, this project is developed as a management the power supply for user to reduce the cost of energy consumption. Through this system, it will automatic manage the power supply as a green energy is primary resources and TNB power supply as standby source while the battery is running out for reduce power consumption and also to optimize the used of battery.

1.3 Objectives

The objectives of this project are:

i. To develop an automatic management power supply from TNB or Renewable Energy (RE).
ii. To control the system based on state-of- charge (SOC) of battery (limit to 30%).

1.4 Scopes

The scopes of the project are:

i. This project only for single phase power supply.
ii. Supply voltage is 240 Volt with current rating 30 Ampere.
iii. This project measure the voltage and state of charge level on a battery that charge from the photovoltaic system.
iv. This system utilizes the ARDUINO as a microcontroller as the switching system.

1.5 Report Outline

This report contains of five (5) chapters start with the introduction chapter that consists of brief explanation of the research which is Green Energy Management System (GreEMys) and why it is proposed. The objectives, scope and the significant of the research also presented in this chapter. Other chapters in this report are arranged as follow:

CHAPTER 2 discuss about the literature review for this research. This chapter is including an explanation about the utility system, RE, SOC of battery and previous project. The various types of selector of power supply topologies and measurement of the SOC for battery also will be described in this chapter.

CHAPTER 3 discuss about the methodology for this project. All the methods used in accomplishing this research are explained and all the flowchart and milestone are presented in the earlier section of this chapter. The concept of GreEMys also will be discussed in details with the help of particular flow chart, figure, and block diagram. The diagram of circuit and implementation of hardware also will be presented.

CHAPTER 4 gathered all the results get from the testing of the circuit and coding are taken for analysis. The result gathered is discussed in details in this chapter.

CHAPTER 5 shows the conclusion and recommendation of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will be discussed regarding on literature review conducted in order to gain enough information that can be used to complete the research. All the data are included in this chapter are taken from journals, thesis, books and any academic articles that are related to the research topic and will be clearly cited. The National Energy knowledge, solar system installation and calculation SOC of battery are discussed in subsequence so that it can be clearly understood. The related previous work such as Uninterruptible Power Supply (UPS) system also presented.

2.2 National Energy

Tenaga Nasional Bhd (TNB) is a largest supplier electricty in Malaysia. There are consist of three main core activities for manage the power supply namely generation, transmission and distribution. TNB also commite with the renewable energy and has been diversifying generation from mix source energy. The genertaion are mix from the fossil fuel, hydro and Renewable Rnergy (RE) such as solar energy and also being efforts producing electricity using biogas and biomass. Figure 2.1 shows the electricity network illustration tie into house from generation plant to the distribution and load [1].

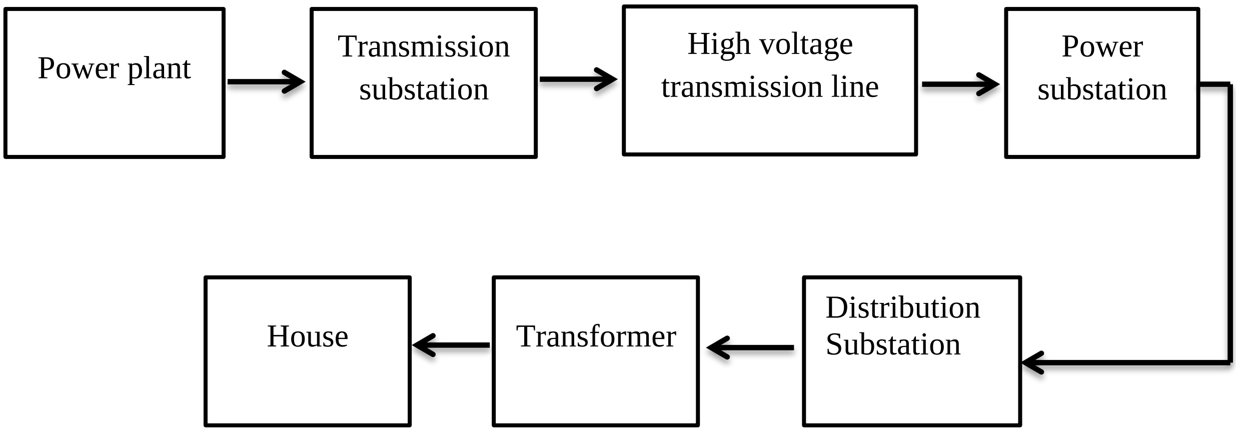

Figure 2.1: The electricity network illustration tie into house.

2.3 Renewable Energy (RE)

RE is a source comes from naturally such as biomass, biogas, solar, wind and mini-hydro. Malaysia is well rich natural resources due to an extremely moderate climate around the years. Most of these energy resources are yet to be exploited. Thus, RE technology could be the alternative source for the energy production include water (hydroelectric and marine energy), solar (thermo and photovoltaic), wind (single turbine or wind field), Geothermic sources and biomass. Geographically, Malaysia is located at the equator and solar energy resources are abundant and readily available for this project [1].

2.3.1 Photovoltaic (PV) Power System

PV power system consists of Photovoltaic panel, inverter and load as a receiver as shown in Figure 2.2. Photovoltaic panel are convert energy from sunlight into electricity in Direct Current (DC) power without any intermediate step. Inverter is required to convert Direct Current (DC) into Alternating Current (AC) power for house appliances. The power is provided by the PV panel which is proportional to PV size. This system is not maintenance free to keep it running optimally but a minimum level of maintenance is needed. To ensure the system operate efficiently, maintenance is a solution to prevent problem in future [2].

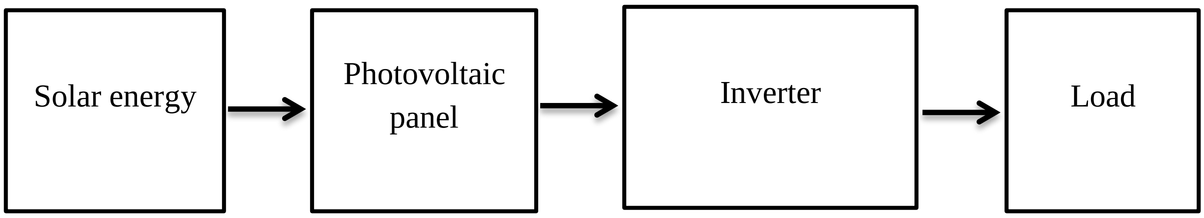

Figure 2.2: The basic home solar system.

2.4 Energy Storage

Energy can be store into battery by holding difference electro-chemical active materials. Therefore, battery can be generated and stored free electrons for a long periods of time. Existing of the chemical inside the battery allows battery to store energy chemically as bi-product of a chemical reaction. Since electrical charge has a polarity, a battery also contains positive terminal (+ve) and negative terminal (-ve). If it polarity is opposite of its own polarity, the charge at battery will try to travel towards the polarity [4].

2.4.1 Battery for Solar Energy

Lead-Acid Battery is chosen to store energy from PV panel for this project. It calls Lead-Acid Battery because the electrode and grids are made from lead and the electrolyte is sulfuric acid. The plate polarity is determined by an active material from some formulation of lead oxides. It is because an active material is placed in physical contact with the grid. Basically, the most common purpose of battery is to start an engine. It is use to energize the starter motor that turns on internal combustion engine. Second, the battery used as stand-by-mode waiting to provide backup power for substation. Third is a deep-cycle application such as the battery can deliver the majority of its capacity repeatedly, possibly on a daily basis. Typically use for Electric Vehicle (EV) application is like a combination of engine start and deep-cycle. Therefore, deep-cycle is suitable for this solar system while charge and discharge sequence are do rapidly [8].

2.4.2 Battery Measuring Method

The lead-acid battery is widely used in stand-alone solar power systems. For reliable operation for this GreEMys system, it is importance to know the amount of battery remaining in the battery at any point of time. The life of the battery will be reduced due to the deep cycle. Damaging effect is also happened to battery while the battery frequent overcharging. Thus, it is necessary to indicate the State of Charge (SOC) of battery to utilize the battery.

SOC of battery indicates the amount of available energy expressed as the percentage of the rated energy. The SOC of the battery is between 0% and 100%. The SOC for fully charged battery is 100% and for an empty battery is 0%. The variation in the battery voltage is very small [3]. Hence SOC can be expressed by the available capacity (AHr) as the percentage of the rated capacity (AHr).

$$SOC = \frac{Ah\ capacity\ remaining\ in\ the\ battery}{Rate\ Ah\ capacity} \times 100\% \qquad (2\text{-}1)$$

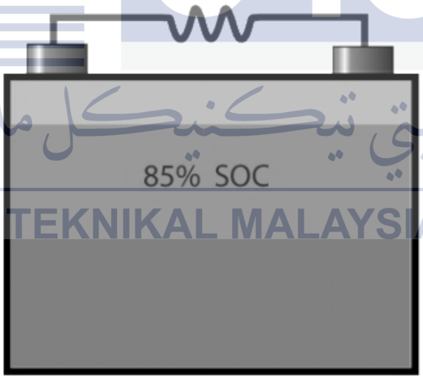

Figure 2.3: The illustration for the SOC of battery.

Through this project, specific gravity method, open circuit voltage method and current integration method have been proposed to determine the SOC of battery. The battery voltage and current have to be monitor to ensure that battery never operated in an unsafe region. The accuracy calculation of SOC can be effect to the system because the SOC value is used to control GreEMys system. These methods are discussed below [3].

A. Specific Gravity Method.

For this method, give the concentration of acid in electrolyte. The concentration of active material and the active material is consumed when the battery discharged. Available capacity of the battery by using specific gravity method can be obtained in direct indication. The measurement of this method is involved by removing the electrode from the battery. The acid specific gravity and charge level is indicated in the Figure 2.4. According to the graph, it show that overcharged for specific gravity is above 1.3 per cell and very low capacity from 1.13 until 1.15 per cell while discharged for specific gravity is below than 1.12 per cell.

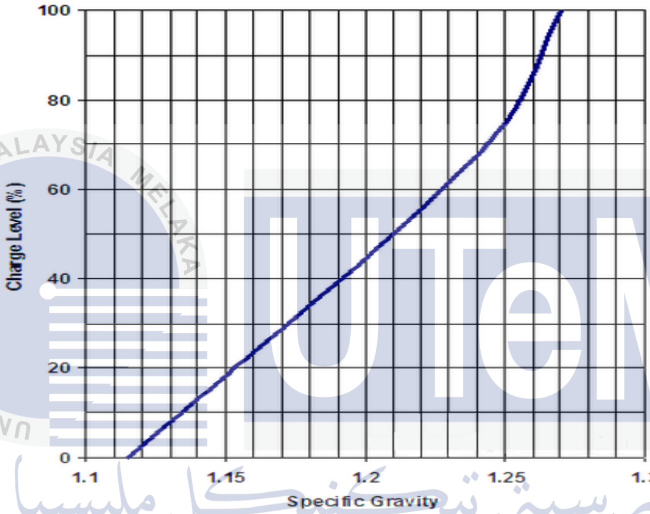

Figure 2.4: Acid Specific Gravity and charge level.

B. Open Circuit Voltage

This method is concentration of acid near electrodes. The SOC of this method is linear function of the open circuit voltage. The length stabilization method time is same with specific gravity method. Refer to Figure 2.5, 2.10 volts/cell is considered to be fully charge and completely discharge when voltage is 1.95 volts/cell. Thus, variation of open circuit voltage is linear to the SOC of battery [3]. SOC can be calculated by using the relation below (2-2) where, Voc is the open circuit voltage of the cell.

$$soc = \left[\frac{200}{3} \times V_{oc}\right] - 1300 \quad (2\text{-}2)$$

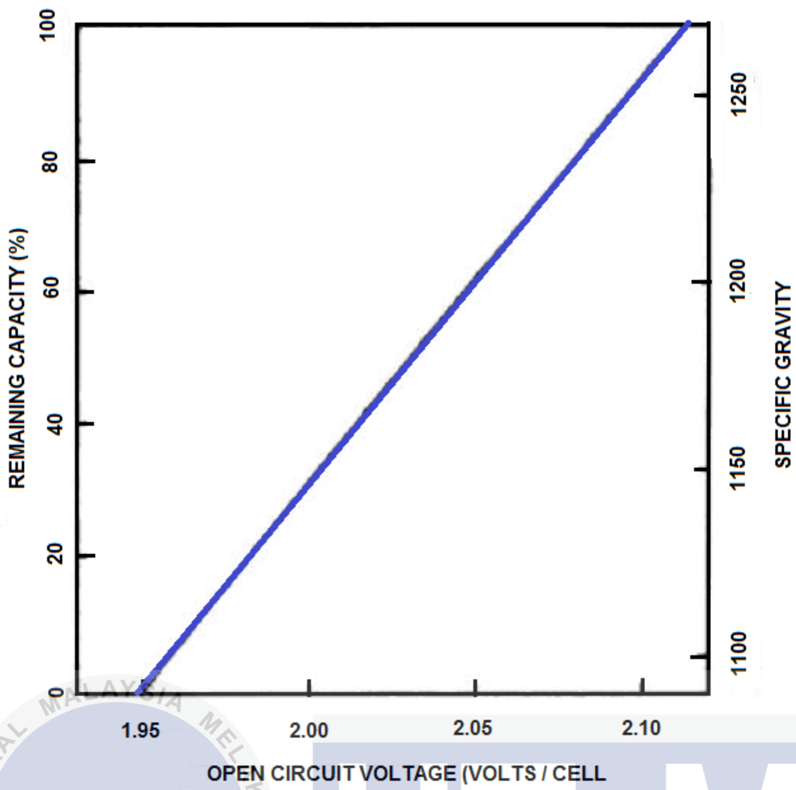

Figure 2.5: Open circuit voltage versus remaining capacity and specific gravity method.

C. Current Integration Method

It is a process of summing the amount of capacity taken from current flowing or out of a battery. Integration method for this current over time is in order to determine the battery capacity [3]. The integration of current is referred as Coulomb counting can be mathematically represented as:

$$SOC = 100\left(1 - \frac{1}{Q}\int_{t0}^{t} i\,(t)\,dt\right) \tag{2-3}$$

Where, Q is the capacity of the battery and i(t) is the current flowing or out of a battery over time.

2.4.3 Efficiency of Battery

Table 2.1 shows the limitation of SOC for charge and discharge battery. It is importance to care life span and efficiency of battery. For longest life, limitation for battery discharge should stay in the 40% of SOC and above. Sometime near to 30% or 20% of SOC are not harmful, but continuously discharge until these levels will be shortening battery life considerably. If the batteries discharge until 10%, it will harm the battery. The voltage measurements are only approximate but the best to determine the SOC is by using specific gravity method [5].

Table 2.1: The approximate of SOC and voltage per cell by using specific gravity method.

SOC (%)	Battery level (volt)	Volts per Cell
100	12.73	1.277
90	12.62	1.258
80	12.50	1.238
70	12.37	1.217
60	12.24	1.195
50	12.10	1.172
40	11.96	1.148
30	11.81	1.124
20	11.66	1.098
10	11.51	1.073

2.5 Arduino

Arduino is a microcontroller board that can be programmed to perform a desired computing function. For example, it can be programmed to process data received from the input ports before sending it to a connected output device. It is often used in an embedded system where it acts as a middle-man to receive process and transfer input data from a source to an output peripheral. Generally, the Arduino board consists of a processor, power supply, input/output ports, USB port and extension connectors. The microcontroller chip used on an Arduino board is an Atmel based Microcontroller. A voltage regulator is available on the Arduino board. The function of this voltage regulator is to convert external source voltage from the range of 7 V-12 V to a regulated 5 V DC voltage. This 5 V will be used as the power source of the Arduino circuit board.

The number of I/O ports available in an Arduino board differs for each model. In the Arduino board, there is a crystal oscillator that generates a clock pulse for the process of the microprocessor. The speed of the microcontroller in executing an instruction is based on the frequency of the clock pulse. The USB port provides a means of communication between the Arduino board with the computer for programming purposes. Besides, the USB port offers another way of powering on the Arduino board as the 5V voltage required to power up the Arduino can be supplied to the Arduino board directly from the computer [18].

2.6 Review of Preview Related Works

This section is discussed about the previous related work. There are three (3) products are related to this project which is Four Start Backup 4400, The Toshiba eneGoon Backup Power Supply and Victron Energy Solar Switch.

Figure 2.6: Four Start Backup 4400.

This product is presented for an emergency battery backup for home. This compact product is produced by Four Start Solar. This 240 volt backup power unit incorporated an inverter that monitors the grid for disruptions. When the grid goes down or is disconnected, the inverter switches to battery backup in less than a second, keep your critical loads online until the grid comes back. The battery bank of the Four Star Backup can be charged with grid electricity, or by generator, or by solar panels. They can also be expanded by adding additional batteries [20].

Figure 2.7: The Toshiba eneGoon Backup Power Supply.

Toshiba's eneGoon backup power supply is made with Super-Charger Ion Battery (SCib). This product was developed by Toshiba and has capacity of 6.6 kWh, which is a best-in-class power output of 3.0 kVA. The eneGoon is connected to a power distribution board. This system can be charged in about five hours in the normal mode and in about two hours in the rapid charging mode. The high combination with quick time makes it easy to take advantage of cheaper off-peak electricity rate to keep the unit fully charge. If power failure, electricity is supplied to selected loads and helps reduce power consumption during peak hours by using electricity that was stored at night during the daytime when demand is high [23].

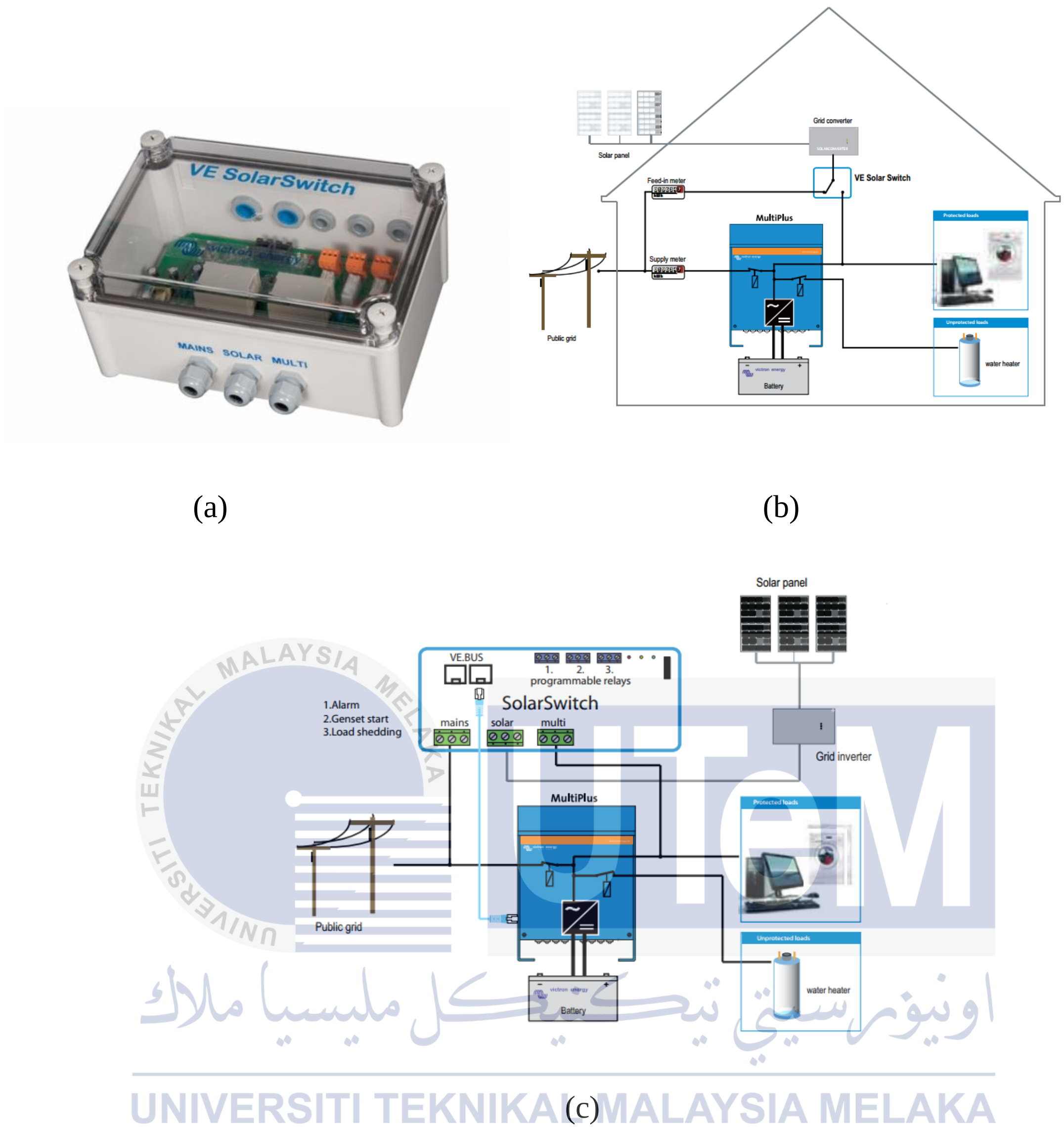

Figure 2.8: (a) Victron Energy Solar Switch (b) Schematic system for setup (c) Schematic wiring for Victron Energy Solar Switch.

This Victron Energy Solar Switch system is produced by Victron Energy BLUE POWER. This system were operated that combine with MultiPlus system or other system. Victron Energy Solar Switch will connect to input and output terminal such as main system, solar and MultiPlus. If the grid fails, MultiPlus will function to feed the load. Once the batteries are fully charged, the excess power from solar can be redirected to a water heater. Thus, in case insufficient solar power while the batteries in used, some or all loads can be shut down to prevent batteries from discharge completely [24].

2.7 Summary of Review

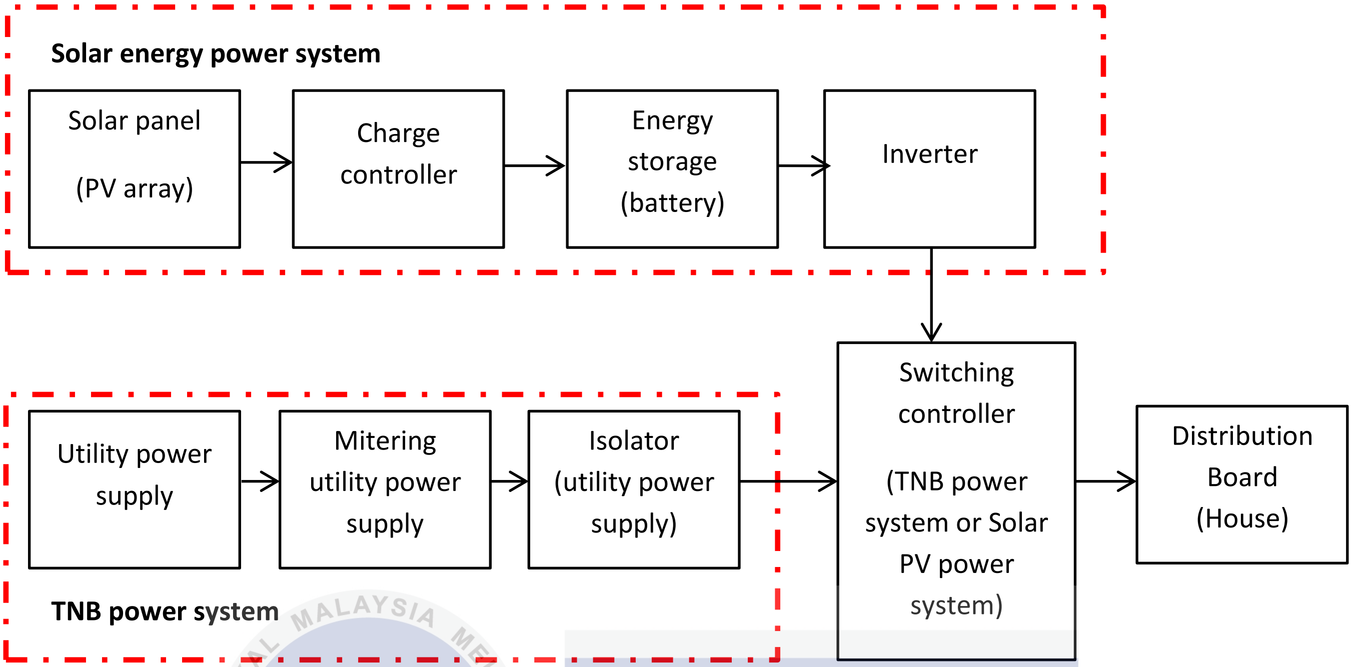

Figure 2.9: The topology of the switching control the solar PV system with tie utility system.

From the literature review, it can be concluded by using topology base on Figure 2.9 Power supplies are produced by TNB and RE were supply to the load demand. RE is generating by the solar energy. Solar energy shall convert to AC supply for general used as TNB supply. When the houses or other building are being fitted with grid connected solar installations, thus some system is needed to manage the power supply to feed the load demanding.

To calculate SOC of the battery, combination of specific gravity method and open circuit voltage are used for compared with the integration method for determine the accurate measurement. The efficiency of the battery is between 30% for discharge and 100 % for charge. Thus, the limitation of this auto selector to switching for discharge from RE to TNB is start from 30% while switching for charge from TNB to RE is start from 100%.

CHAPTER 3

METHODOLOGY

3.1 Project Methodology

The methodology of this project is shown in Figure 3.1. This project is started with literature reviews that give idea and better understanding about the Solar Energy system. The process of literature review is search for journals, articles, internet and book and analyzed the relation to the system of this project.

Then, setup the solar system with battery. The solar panel is connected with the charging controller, battery and into the inverter. Thus, the connections are tested for the functional of the system. If does not, it will setup again.

After succeed setup solar power system, designing the selector controller by using the Arduino as microcontrollers will be proceeding. The coding must be suitable with the implementation that will be communicated with the hardware. Thus, the project precedes a new circuit to measure the desired SOC of the battery. The SOC is the reference to the switching for select the condition of the switching.

The following task is to ensure that the combination between hardware and coding will fulfill all the specification and achieve the objective. In addition, the data or result must relevant with the system. After everything is completed, the testing is carried out to ensure that the system works perfectly. In conclusion, the analysis and troubleshooting for this project will carry out through the expected result.

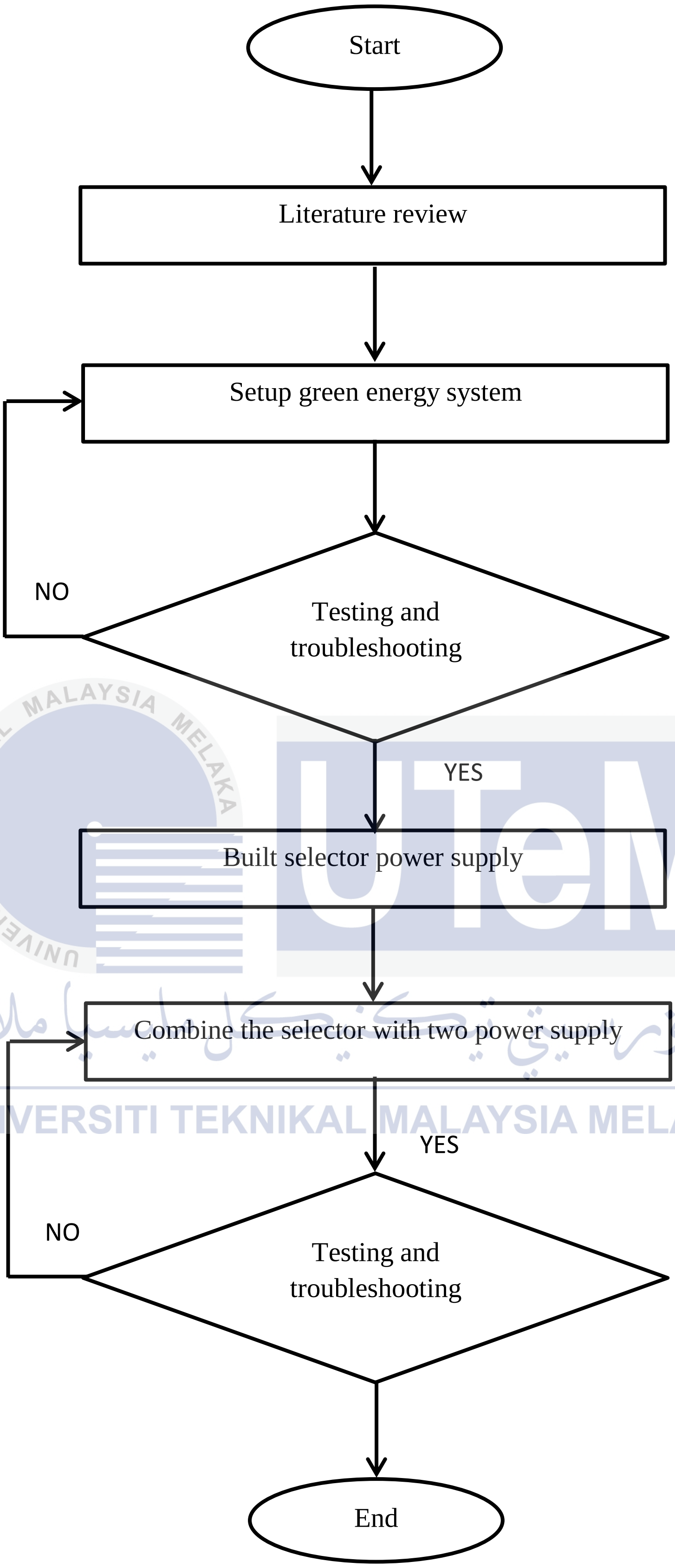

Figure 3.1: The methodology of the project.

3.2 Project System Design

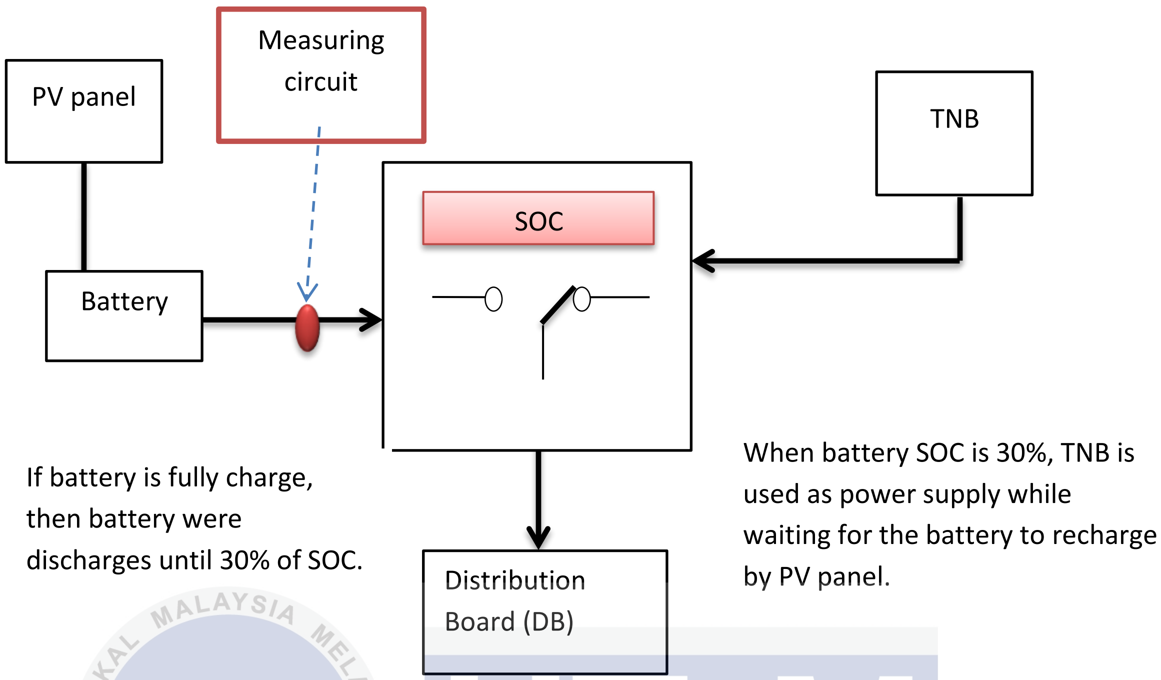

Figure 3.2: Block diagram of the project.

The Figure 3.2 shows the block diagram of the project. This system is developed as a management system for user to reduce the cost of electricity consumption. Through this system, the LCD is display the status of SOC for battery and the selector will choose battery as priority energy to reduce usage of electricity from TNB. If the battery is weak (about 30%), the system will automatically change to TNB power supply while for the battery to recharge by green energy. This process will continue and thereby reduces the cost of electricity.

3.3 Hardware Development

In this project, there are three (3) types of software been in used which are Proteus, Arduino software and orCAD. These tools are used to develop software test design before implementation in actual life is build. This tool can reduce cost of building with no mistake while the components are used in not match with the design.

3.3.1 Proteus software

Protuse is a toll that can combine electronic component on it library. It simulation can be run in real word, while the connection are wrong, this toll will display the warning message. This tool ability to simulate popular microcontroller and it can reduce are development time compared with a tradisional design process.

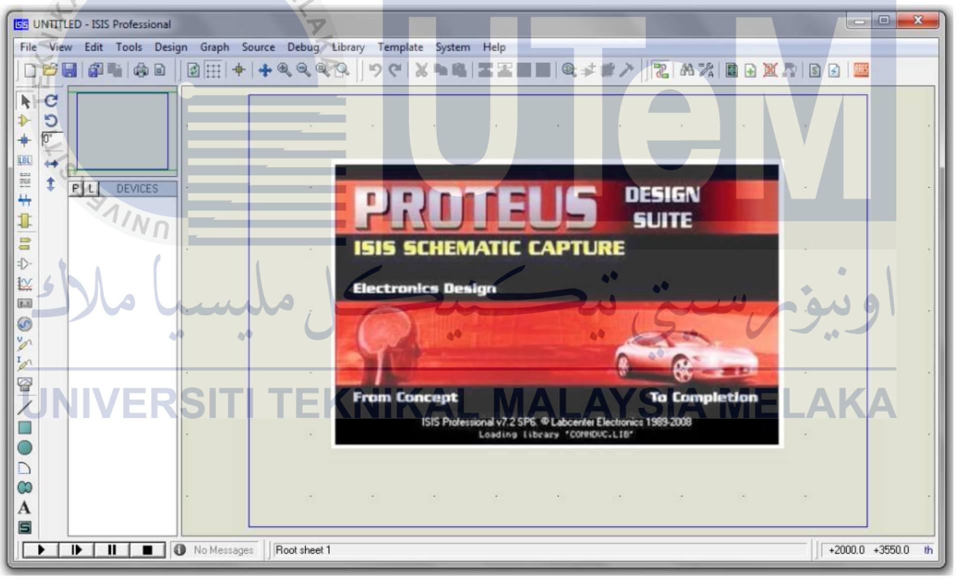

Figure 3.3: Proteus software.

The Figure 3.4 shows the flow chart of the design circuit. Firstly, the planning for the design must be considered. Input and output of the component should be determined. Through this project, voltage divider and current sensor are considered as an input and internal relay as an output. This input and output component are interface with Arduino microcontroller. When the design is functional well, the Arduino coding in .hex file will be imported to the Arduino microcontroller. The screen and internal relay were shows the result of the combination from two software.

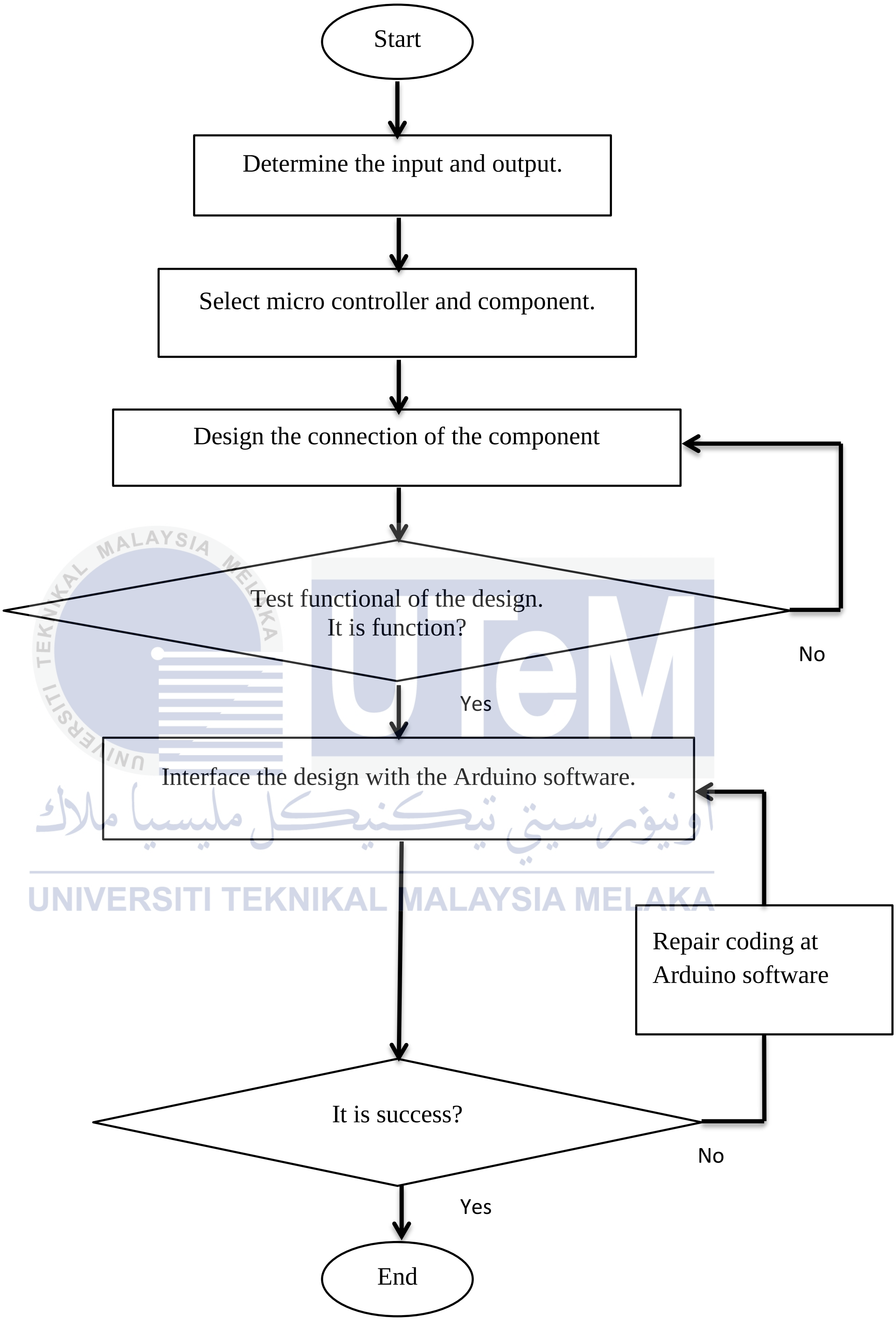

Figure 3.4: The flow chart of the design circuit.

Figure 3.5 show the simulation for test the circuit. The arduino microcontroller are import from the Proteus Library and the coding are tested with the circuit was build in this tool. There are 3 section of the circuit which is measurement part, display part and switching part.

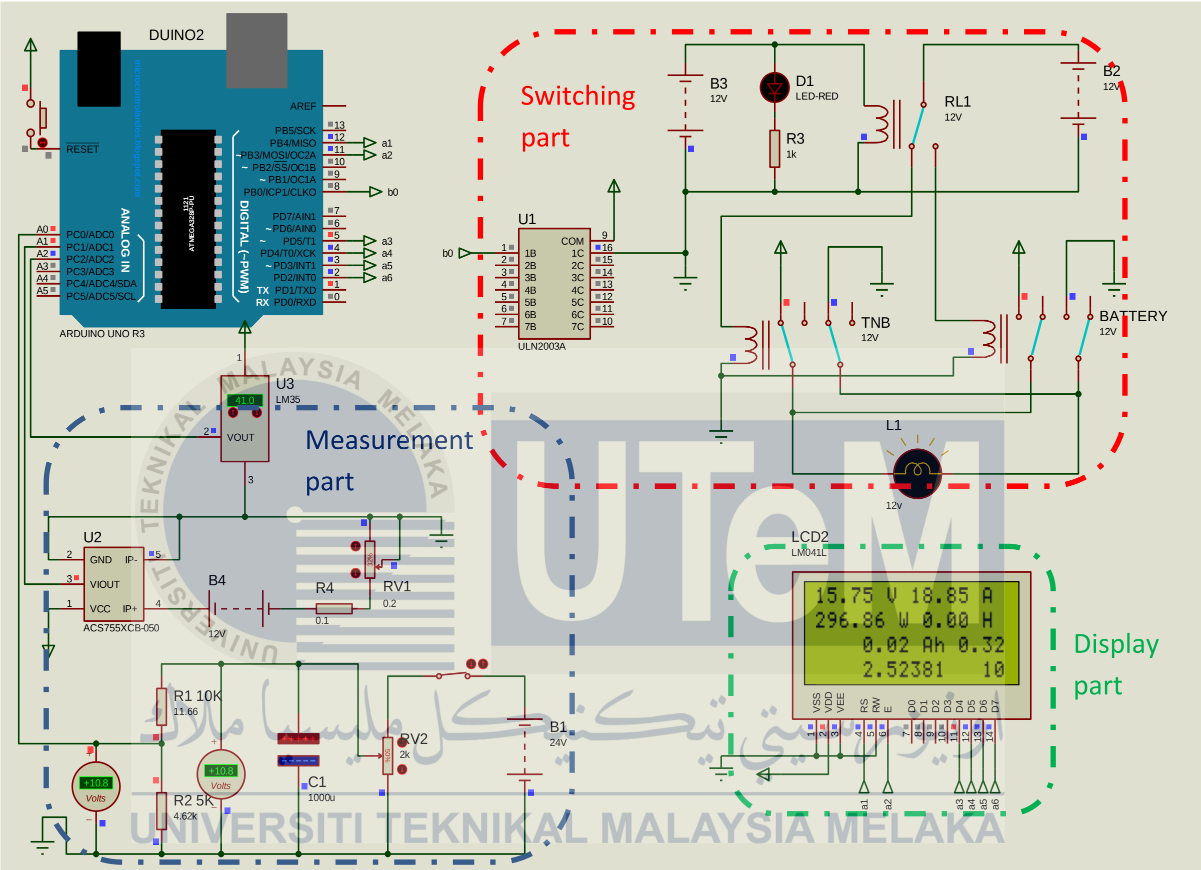

Figure 3.5: Proteus simulation testing.

Figure 3.6 show the step of Proteus to import the .hex file from the Arduino microcontroller. The .hex file is browse from the icon provided at the file program. When the found, and click ok. Then the simulation can run and the result will display on screen.

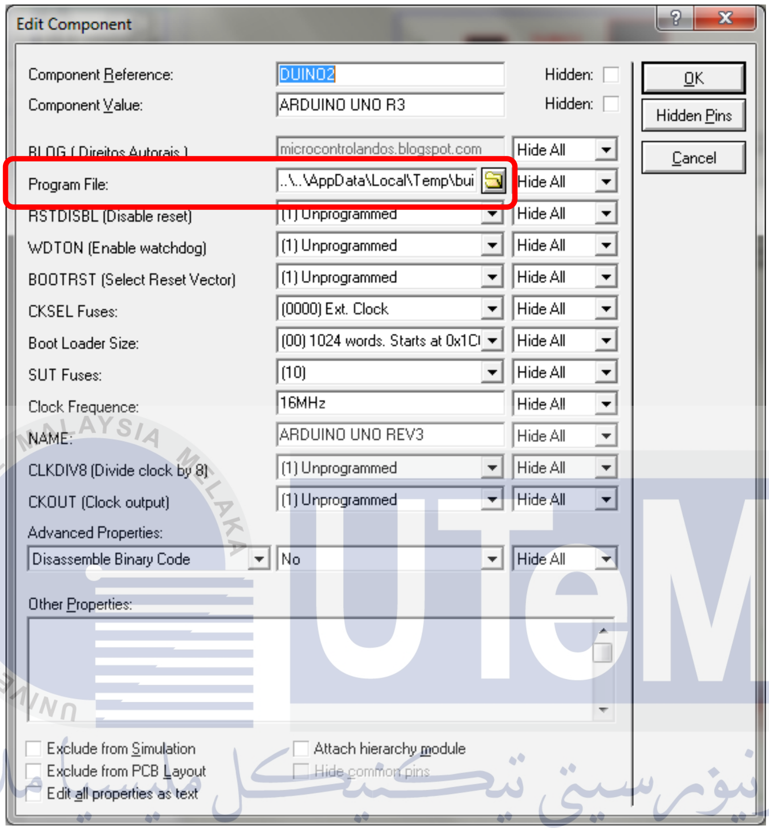

Figure 3.6: Import .hex file.

3.3.2 Arduino

Arduino is the software to write the coding of the program. This software is necessary to flash the coding that have compile into .hex file to Arduino. The popular and powerful Arduino are it can be stand-alone and the program language are special and easy to design with related on wiring that connected with Arduino board.

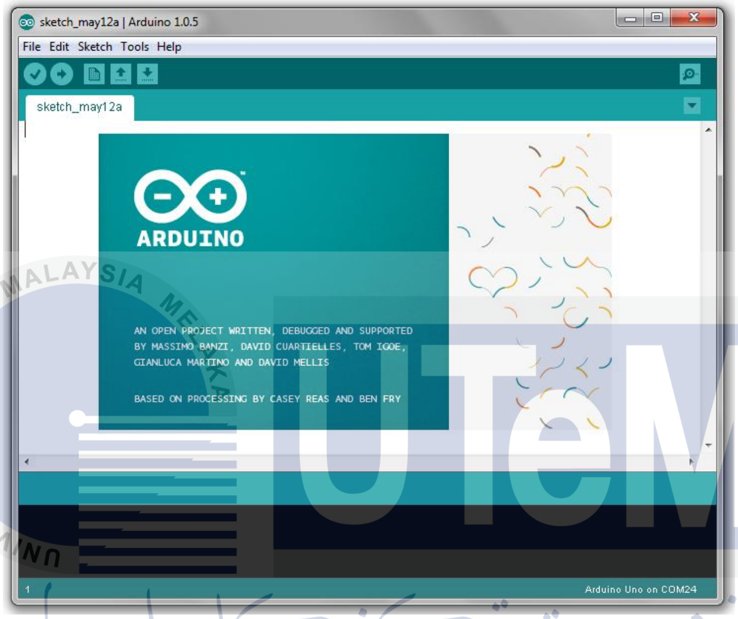

Figure 3.7: The Arduino software.

Figure 3.8 shows the flow chart before made coding in Arduino. They are two conditions to follow for manage the power supply. The conditions depend on the SOC from the battery condition. When the battery used until SOC drop to 30%, this system will be changed the hybrid power supply into the TNB power supply. While the battery charge by using Renewable Energy (RE) until the SOC increases until 100%, this system is changed back to the hybrid system to optimize the used of battery. This system is looping all the time when these systems are used.

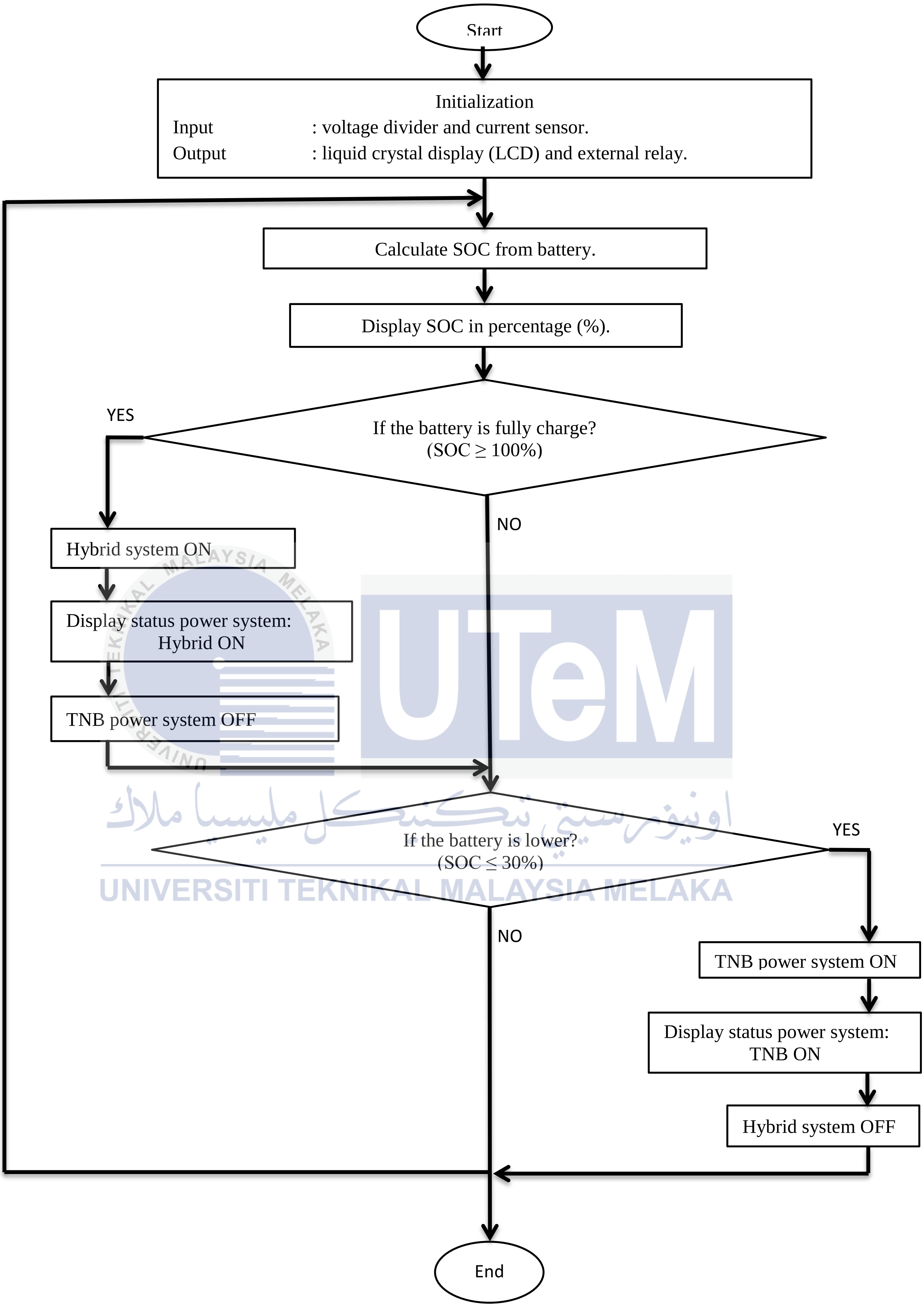

Figure 3.8: The flow chart of the management power system.

3.3.3 OrCAD Capture

This layout design by using OrCAD Capture, it is the one of the most widely used schematic design solutions for the creation and documentation of electrical circuits. Coupled with the optional OrCAD CIS (component information system) product for component data management, along with highly integrated flows supporting the engineering process, OrCAD Capture is one of the most powerful design environments for taking today's product creation from concept to production.

Figure 3.9: OrCAD software.

This tool is used for design Printed Circuit Board (PCB). The holes for screw, pads and wire for the circuit are creating to PCB design. Before start, the areas of components are measured. This component will be rearranged and attach above of the PCB. The circuit was design from Proteus and PCB design process by using OrCAD layout.

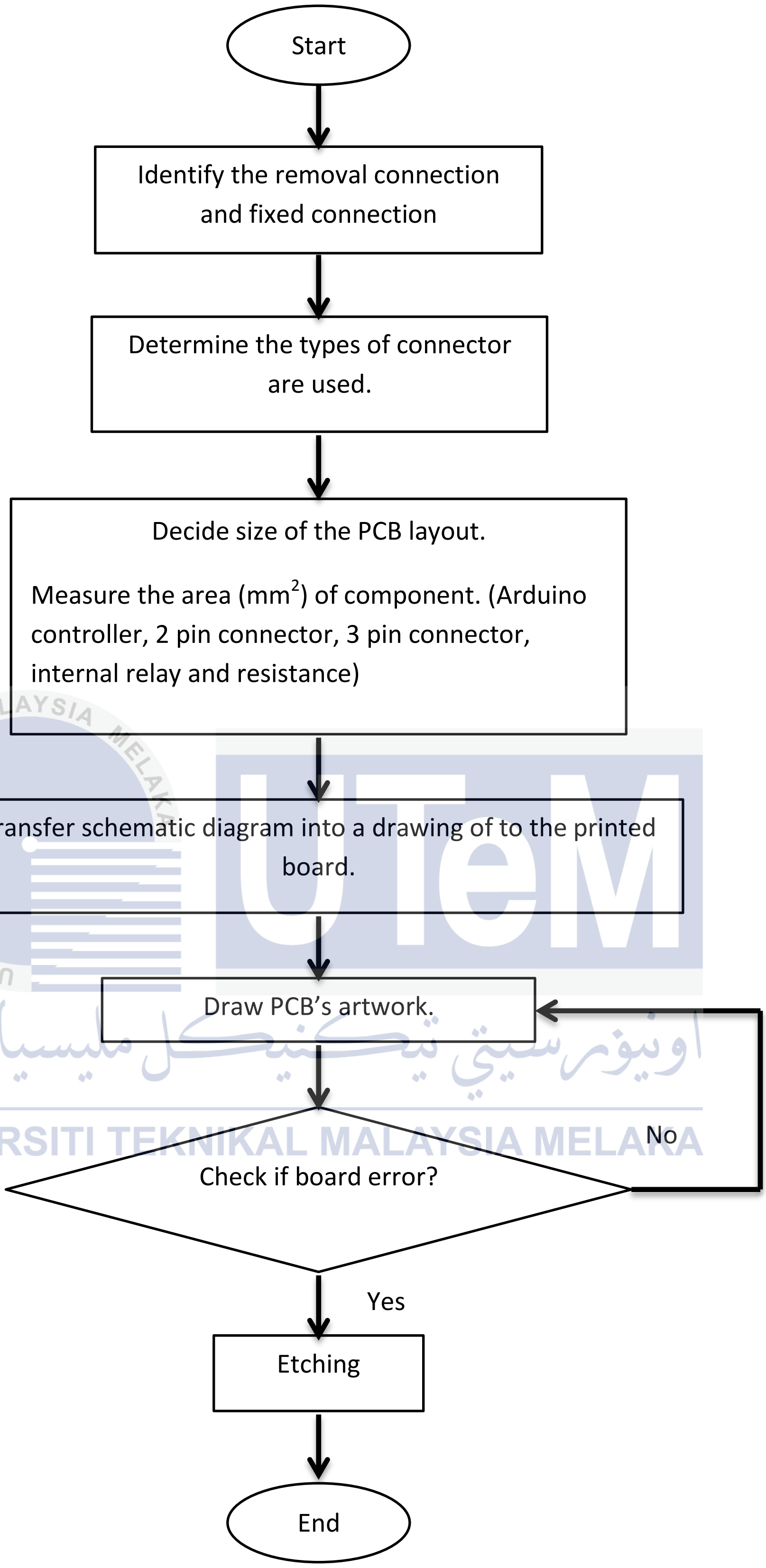

Figure 3.10: Flow Chat of PCB design

Figure 3.11 show the connection of input and output terminal. The combination of the circuit is to make the PCB board. These connections are integrated with LCD screen pin, sensor pin, relay pin and led pin.

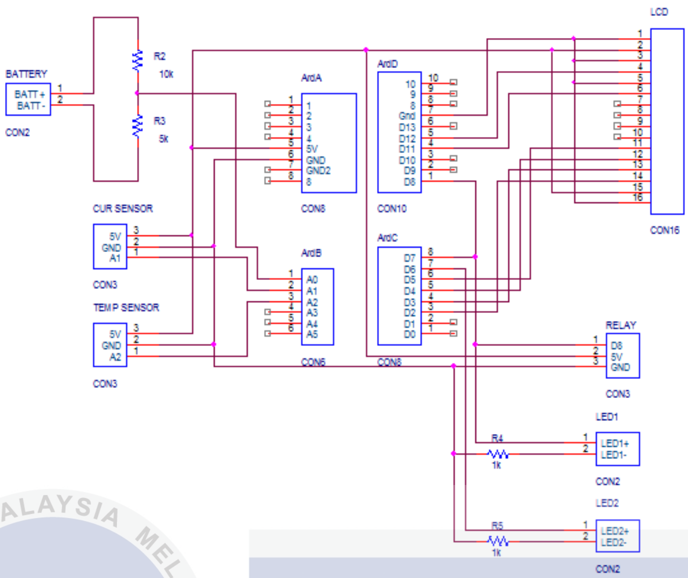

Figure 3.11: Schematic capture through the electronic design.

Figure 3.12 show the designed PCB layout from OrCad tool after arrangement of the line connection. The layout is used to print and trace on board then dried in to the sun or light. While the board is already tracing, then the board are aching by using chemical liquid.

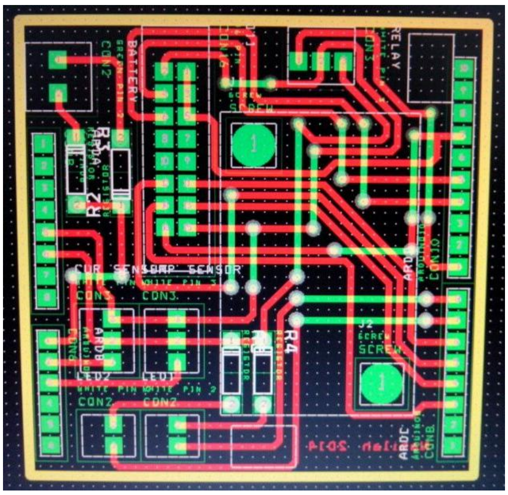

Figure 3.12: Complete design PCB layout.

3.4 Measurement Circuit

The measurement circuit is used to calculate the voltage remaining at the battery and to calculate the current flowing and out from the battery. Thus, the microcontroller Arduino will calculate the parameter by using voltage divider for detect voltage level voltage and current sensor to detect current.

3.4.1 Voltage divider

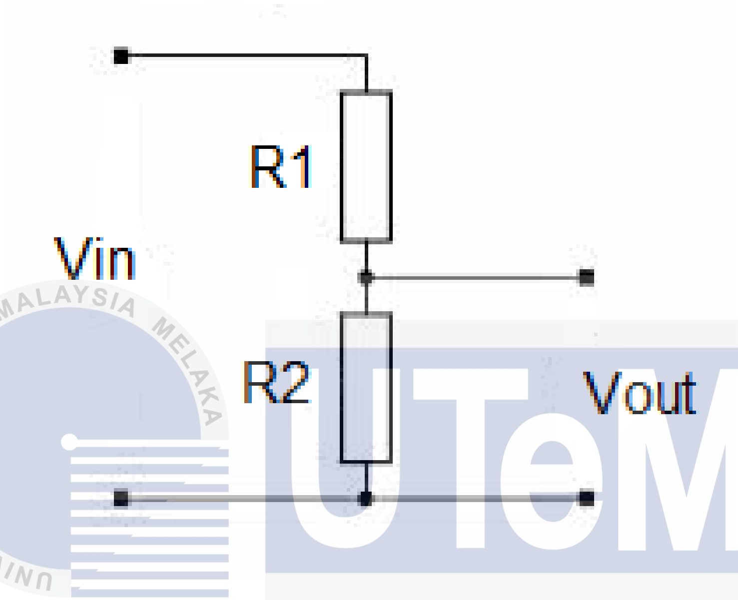

Figure 3.13: Voltage divider.

While using voltage divider, two resistors is used to supply voltage difference from power supply or battery. The output voltage depends on the value of resistor. The theory can be considered, if large value of R2 compared to R1, it will gives a large value of output voltage. It is commonly used to create a reference voltage or to get a low voltage signal proportional to the voltage to be measured.

3.4.2 Current Sensor

Figure 3.14: The current sensor BB- ACS 756.

There is wide range of electronic system that used current sensing. It is a device that detects and converts current to an output voltage with range 0V until 5V, which is proportional to the current through the measured part. This current sensor is based on IC ACS756. The IC has linear voltage output equivalent to current with sensitivity of 40mV/A. Thus, every rise current of 1A will increase 40mV to VIOUT pin. [22] By taking the ratio and sensitivity of the sensor, it can be write as

$$I\ (mA) = \frac{(sensor\ reading - 510)}{0.04V} \cdot \frac{5V}{1024\ bits} \cdot (1000mA) \qquad (3\text{-}1)$$

3.5 Hardware Implementation

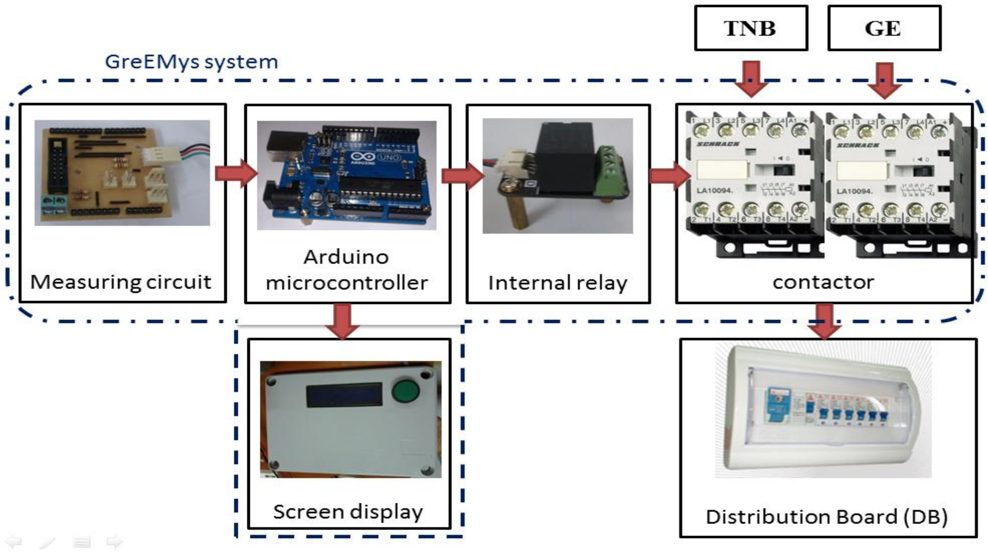

Figure 3.15: The illustration of interface the GreEMys with power supplies.

Figure 3.15 shows the circuit interface circuit of the system with the power supplies. Inside the GreEMys consists of the Arduino microcontroller, internal relay, contactor and LCD screen. This system is used to manage which GE is a priority resources and TNB will operate will GE energy are reduce until minimum limit and wait until battery fully charge by green energy. GreEMys system is installed after KWh meter and before distribution board (DB).

3.6 Milestone

Below is the milestone stone set for this research.

Milestone 1 – Research on solar system and selector switching method

Milestone 2 – Study on the Arduino coding

Milestone 3 – Setup the apparatus for testing from solar panel, inverter, battery and charge controller.

Milestone 4 – Built coding and circuit for measure voltage and current from lead acid battery.

Milestone 5 – Validate the data obtain from hardware.

Milestone 6 – Report writing

CHAPTER 4

RESULTS

4.1 Introduction

The purpose of this chapter is to presenting the result of the GreEMys system. The performance of this system will be test and discuss the ability of the system. Additionally, the full integration of the whole project discussed.

4.2 GreEMys System

Figure 4.1 shows the display properties on the screen of the GreEmys system. The screen are display the status of the mode of power supply, battery voltage and the percentage of the remaining State of Charge (SOC) from battery.

Figure 4.1: Display properties on screen.

Figure 4.2 show the screen is display the mode of power supply. When the GreEmys system chosed TNB power supply then the screen is display MODE : TNB and whwn the GreEMys system choosed Renewable Energy (RE) power supply then the screen is display MODE: GE.

Figure 4.2: Display properties of mode power supply.

Figure 4.3 show the display properties of voltage from battery. The screen is desplay the voltage remaining on the battery. Reading voltage of battery is increase while on charge and decreases while the battery is discharge.

Figure 4.3: Display properties of voltage from battery.

Figure 4.4 show the display properties of SOC from battery. The value of SOC is display in percentage (%). The value of SOC is depending on the capacity remaining on the battery.

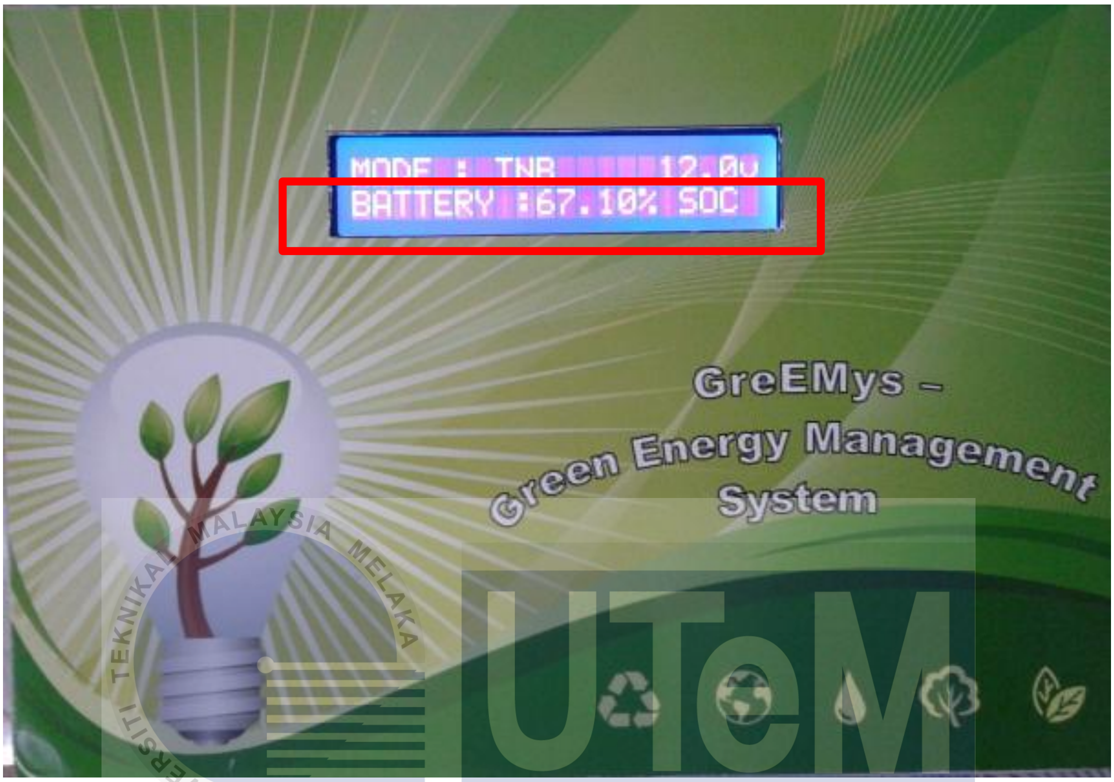

Figure 4.4: Display properties of SOC from battery.

4.3 Project Outcome

The project outcome of this project are described the component and connection inside the GreEmys system. The integrated with the electric component with the electronic component are descripted.

Figure 4.5 shows the connection and combination of component with the Arduino microcontroller. The circuit on PCB will be fixed and the circuit design is not mesh. On the PCB board consist of measurement circuit and internal relay on the second stage. PCB can be designed into two (2) stages or more depend on the creativity from the designer. The sensor are connected with the white connector, it is already build.

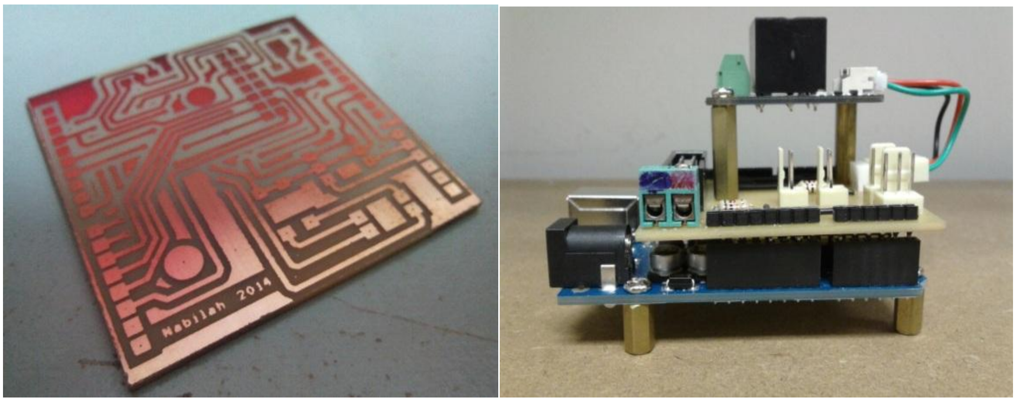

Figure 4.5: The PCB and Arduino microcontroller.

Figure 4.6 show the combination of the electrical and electronic component inside the box. Through this box, it is consist of the contactor, microcontroller Arduino, measurement circuit and battery for power up Arduino.

Figure 4.6: The electric and electronic component inside the box.

Figure 4.7 show the location of the contactors. These contactors are separated with difference sources. One contactor is incoming from TNB power supply and another one is incoming from inverter. This incoming power supply must be separated for safety purpose.

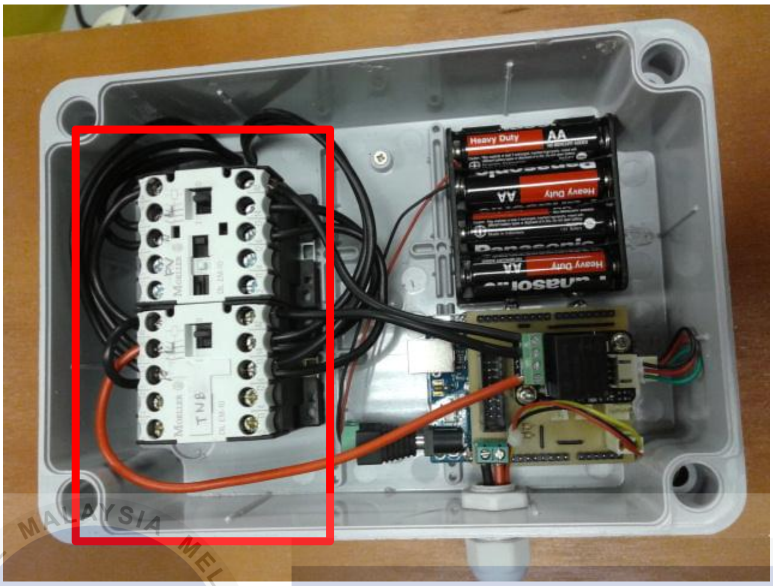

Figure 4.7: The contactors are inside the box.

Figure 4.8 shows position for the Arduino controller. At the top of Arduino is internal relay. Arduino is cannot directly contact with the AC voltage (230Vac), Arduino are only can receive a DC voltage with is in range 0 VDC unlit 5 VDC. Internal relay are used to select the power supply either incoming from TNB or incoming from inverter.

Figure 4.8: The PCB board with the arduino inside the box.

4.4 Accuracy of Measurement

The measurement is taken while the system is online. The reading for actual current is taken by series with the current sensor while the reading for calculate current is by using Arduino microcontroller. Figure 4.9 shows the method of the measurement are taken to compare the actual reading with the calculation reading.

Figure 4.9: The situation while the reading taken.

According to Figure 4.10, the different of the two reading are 0.05A. It is show that the system has error if current reading almost 6%. Thus, according to Figure 4.10, there are reading current from the photovoltaic panel. It is show that the current passing through from the panel to battery is accurate compared to current passing through the load. This error may occur while using the inverter for convert dc supply to ac supply. For actual voltage, Multimeter are tapped in parallel to the terminal battery while the reading for calculate voltage are also by using Arduino microcontroller. Refer to figure 4.10 the actual voltage and the calculate voltage are same, thus no error are exist for voltage. Thus, in this project is only use voltage to calculate the SOC of the battery.

Figure 4.10: The actual reading between calculation for current and voltage.

4.5 The Performances of GreEMys

By using formula (2-2) open circuit voltage to calculate the SOC for compare with the actual SOC by using the digital battery analyzer. The microcontroller was calculating the SOC of battery and select the power supply depend on the level of SOC. The table below shows the performance of the GreEMys system.

Table 4.1: The status mode of power supply depends on SOC condition while battery is discharge.

No.	Voltage Calculate (Volt)	Voltage actual (Volt)	Voltage percell (volt/cell)	SOC calculate (%)	SOC actual (%)	Status mode (TNB/GE)
1	12.74	12.74	2.1167	111.13	100	GE
2	12.68	12.68	2.1000	100.00	98	GE
3	12.55	12.55	2.0833	88.87	85	GE
4	12.43	12.43	2.0667	77.80	74	GE
5	12.37	12.37	2.0500	66.67	65	GE
6	12.28	12.28	2.0333	55.53	57	GE
7	12.14	12.14	2.0167	44.47	46	GE
8	12.06	12.06	2.0000	33.33	34	GE
9	11.93	11.93	1.9833	22.20	20	TNB
10	11.96	11.96	1.9667	22.30	22	TNB

Table 4.1 shows the performance of the GreEMys system while the battery is on discharged. The result table show Mode: GE, the battery is discharge until near to 30% of SOC and the battery will charge by Photovoltaic (PV) panel and the mode of system is change to Mode: TNB to keep the load are running.

Figure 4.11 show the percentage (%) error of SOC between the actual SOC and calculation SOC when the SOC in discharge. The percentage error is less than 5% accept the battery is in full charge is exceed 10%.

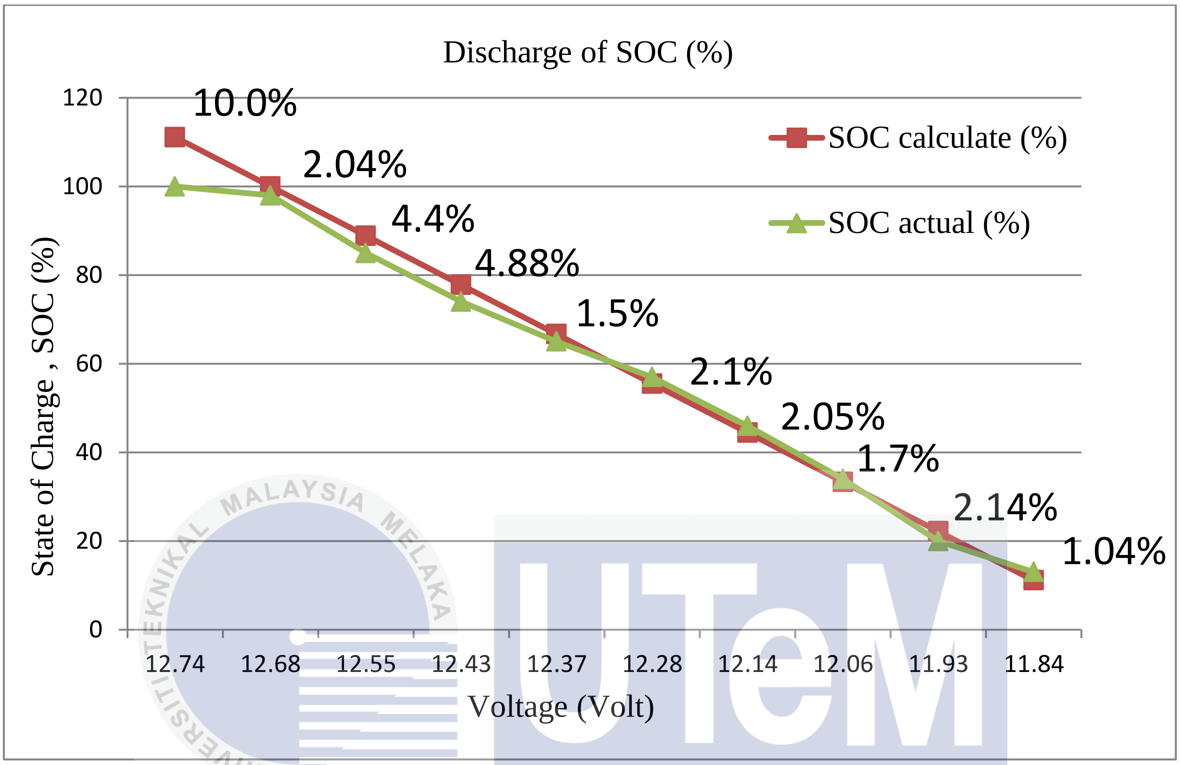

Figure 4.11: The percentage error of SOC when Discharge.

Table 4.2: The status mode of power supply depends on SOC condition while battery is charge.

No.	Voltage Calculate (Volt)	Voltage actual (Volt)	Voltage percell (volt/cell)	SOC calculate (%)	SOC actual (%)	Status selector (TNB/GE)
1	11.87	11.87	1.9667	11.13	14	TNB
2	11.95	11.95	1.9833	22.2	21	TNB
3	12.07	12.07	2.0000	33.33	35	TNB
4	12.16	12.16	2.0167	44.47	46	TNB
5	12.24	12.24	2.0333	55.53	57	TNB
6	12.35	12.35	2.0500	66.67	63	TNB
7	12.47	12.47	2.0667	77.80	78	TNB
8	12.56	12.56	2.0833	88.87	87	TNB
9	12.62	12.62	2.1000	96.00	94	TNB
10	12.75	12.75	2.1167	111.13	100	GE

Table 4.2 shows the performance of the GreEMys system while the battery is on charged by the PV panel. The battery is charge by the PV panel until 100% and the system are changed the mode power supply to Mode: GE. Then, the system is rapidly discharge and charge the battery depends on the SOC of battery.

Figure 4.12 show the percentage (%) error of SOC between the actual SOC and calculation SOC when the SOC in charge. The percentage error is less than 5% when the system is charge mode.

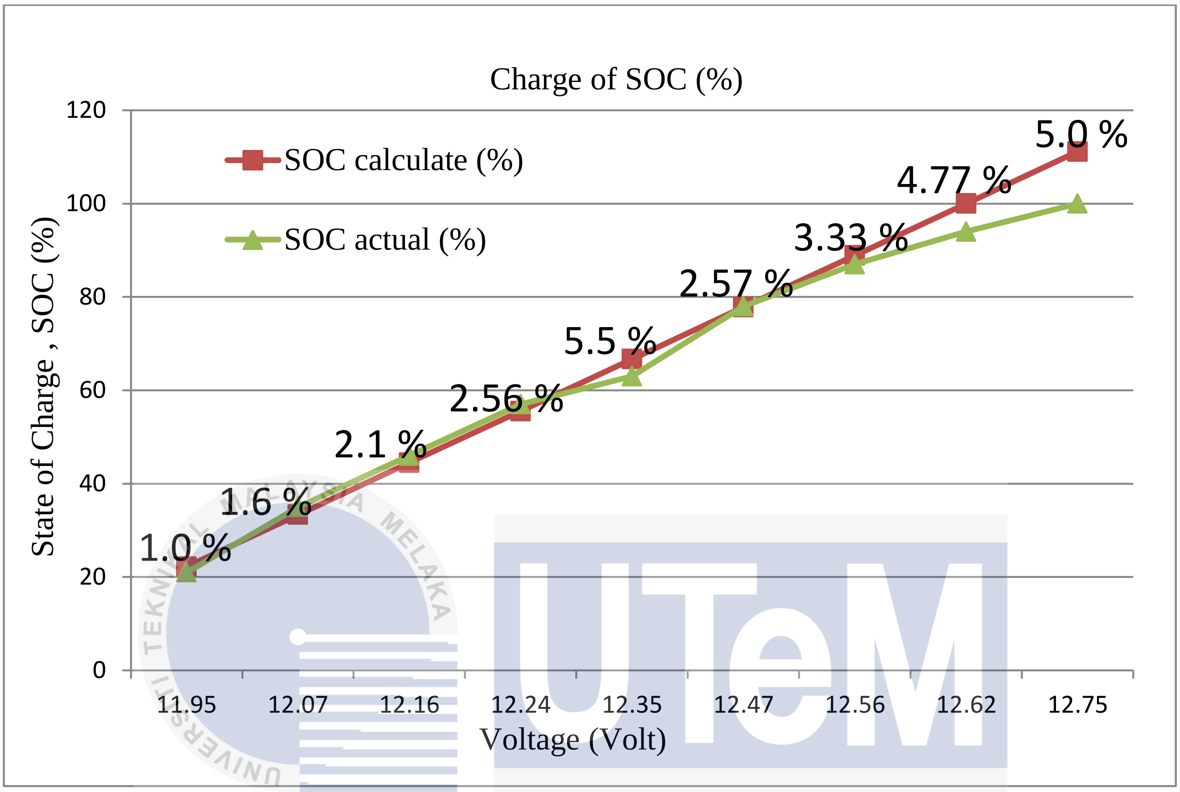

Figure 4.12: The percentage error of SOC when Charge.

The calculation of the SOC with the actual SOC reading is not accurate but the power supply mode is following the target. This system used the GE system as a priority power supply when the battery is fully charge by GE and changes to TNB mode while the battery level is decrease to maximum limit and wait until battery fully charge by GE.

Figure 4.13 show the reading of the SOC calculation and voltage calculation are taken from the Arduino. Figure 4.14 show the reading of the SOC actual and voltage actual are taken from the digital battery analyzer. The readings are taken simultaneously for compare the actual reading with calculate reading.

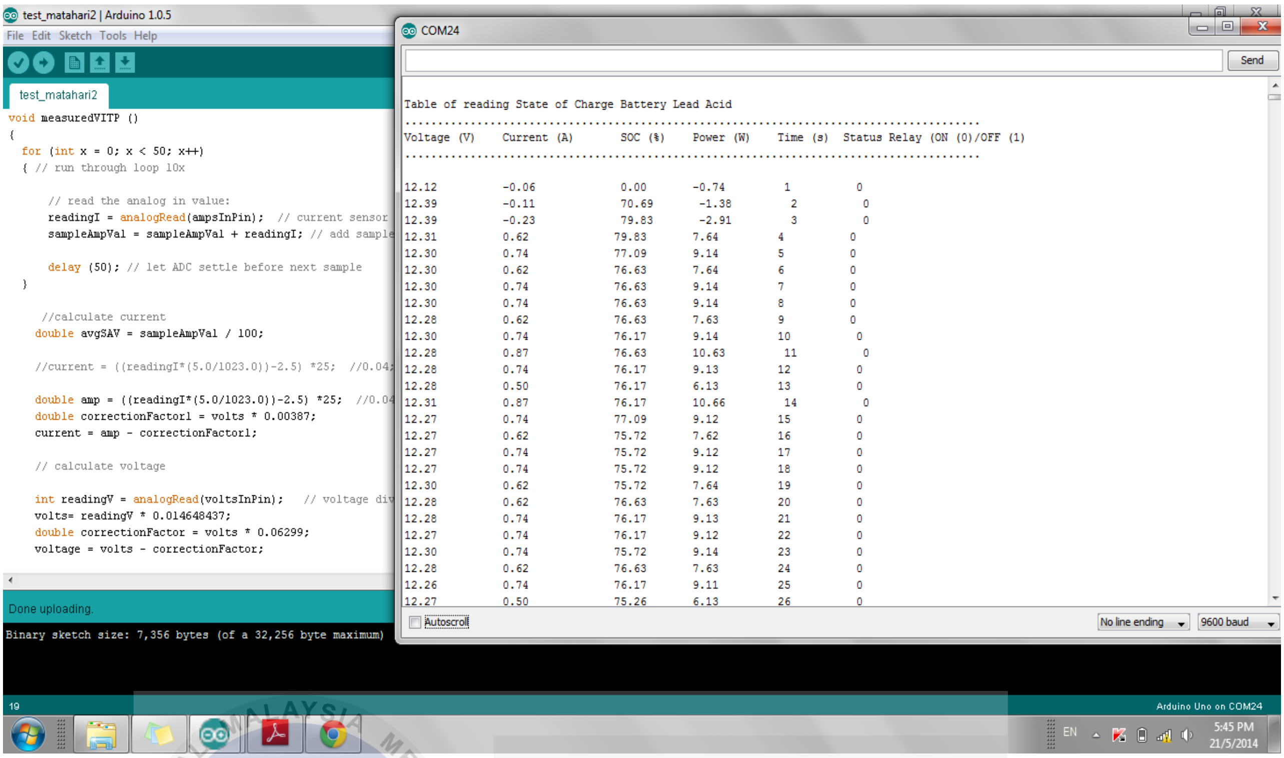

Figure 4.13: Data collected on the Arduino in serial print.

Figure 4.14: The digital battery analyzer.

Figure 4.15 show the implementation of the GreEMys system to the load. The load consist of the socket outlet (SSO) and lamp. The inverter is used to convert DC voltage to AC voltage from the battery, while the TNB power supply is directly used to the load when Mode: TNB are on running.

Figure 4.15: The implementation of the project.

Figure 4.16 show the PV panel is used in this system. PV panel is used to charged battery by using sun light. The GreEMys system is used to control the charge and discharge the battery depend on the SOC of battery.

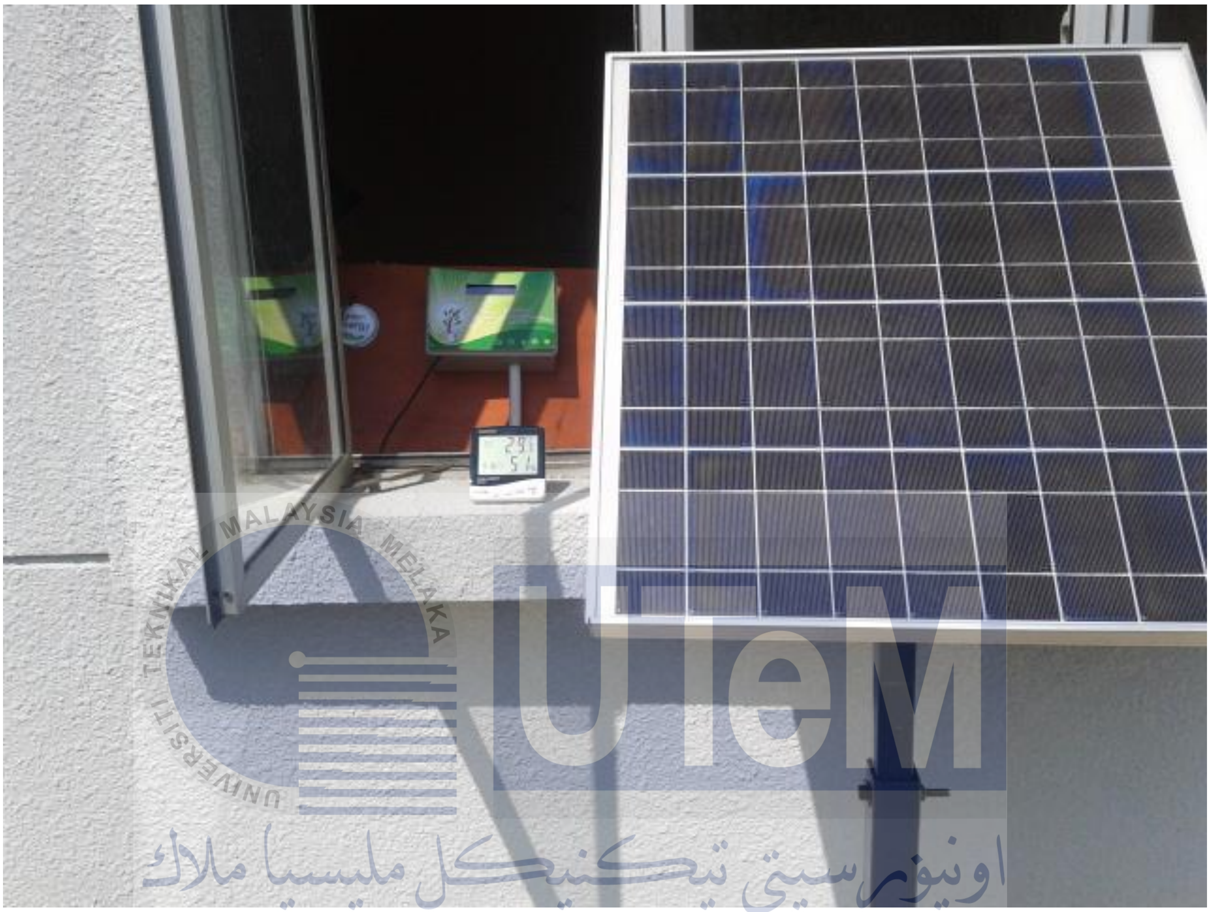

Figure 4.16: The implementation of the project.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This project had presented the design of a GreEMys system that can be used in all green energy user especially solar energy for measured the status SOC of battery. The main objective of the project has been achieved successfully. This system able to managed the power supply automatically. The selection of the source power were operate depend on the status SOC of the battery. This system is able to display mode of power supply, voltage, and SOC as required in the scope of this project. The last objective is the performance of the system is ability to perform well in real application with follow the minimum safety purpose and reliability. As a conclusion, all the objectives of this project are successfully achieved and the user interface can be expected to be implemented in green energy power supply to monitor the status battery.

5.2 Achievement

This project has participated in two competitions. This title has been participating in International Engineering Exhibition Invention & Innovation (i-ENVEX) on April 13th, 2014 and has won a gold award. Second is participating at The International Participation and Design Innovation Expo in conjunction with International Innovation Festival 2014 on 18th May 2014 and also received a gold award.

5.3 Recommendation

Inverter is used to convert dc supply to ac supply. Thus, the inverter must be choosing in right way. When the solar system used 1000W of inverter, the load of demand more than limit of inverter it can support the load. For example, inverter 1000W cannot support cattle with load 1500W. Through this case, the calculation of load demand should be considered to select the best inverter. According to this system, it is use open circuit voltage method to find the SOC. Thus, I would like to recommend to use combination of open circuit voltage and integration method for determine the SOC. It is because implementation of the current integration only for long time will lead to error. The sources of errors in this integration method are the efficiency of the charging process is not 100% and the capacity is depend on the rate of discharge. This new method is use if the battery is not used for more than 30 minutes the SOC is updated using open circuit voltage method.

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APPENDIX A

Gantt chat of the project.

Milestone	Year	PSM1				PSM 2				
	Task	9	10	11	12	1	2	3	4	5
1	Research on solar system and selector switching method									
2	Study on the Arduino coding									
3	Setup the apparatus for testing from solar panel, inverter, battery and charge controller.									
4	Built coding and circuit for measure voltage and current from lead acid battery.									
5	Validate the data obtain from hardware									
6	Report writing									

APPENDIX B

Datasheet of battery 12V 7.2Ah

Powered by

BATTERY ® CSB

GP 1272 ▶ 12V 7.2Ah

GP 1272 is a general purpose battery up to 5 years in standby service or more than 260 cycles at 100% discharge in cycle service. As with all CSB batteries, all are rechargeable, highly efficient, leak proof and maintenance free.

▶ Specification

Cells Per Unit	6
Voltage Per Unit	12
Capacity	7.2Ah @ 20hr-rate to 1.75V per cell @25℃(77°F)
Weight	Approx. 2.4 kg (5.29 lbs)
Maximum Discharge Current	100A/130A (5sec)
Internal Resistance	Approx. 23 mΩ
Operating Temperature Range	Discharge: -15℃~50℃ (5°F~122°F) Charge: -15℃~40℃ (5°F~104°F) Storage: -15℃~40℃ (5°F~104°F)
Nominal Operating Temperature Range	25℃±3℃(77°F±5°F)
Float Charging Voltage	13.5 to 13.8 VDC/unit Average at 25℃(77°F)
Recommended Maximum Charging Current Limit	2.16A
Equalization and Cycle Service	14.4 to 15.0 VDC/unit Average at 25℃(77°F)
Self Discharge	CSB Batteries can be stored for more than 6 months at 25℃(77°F). Please charge batteries before using. For higher temperatures the time interval will be shorter.
Terminal	F1/F2-Faston Tab187/250
Container Material	ABS(UL 94-HB/File E50263)*Flammability resistance of (UL 94-V0/File E88637) can be available upon request.

MH14533(N)

TÜV CERT ISO9001 No.:041005117

RWTÜV ISO 14001 NO.UM 1-12-0045

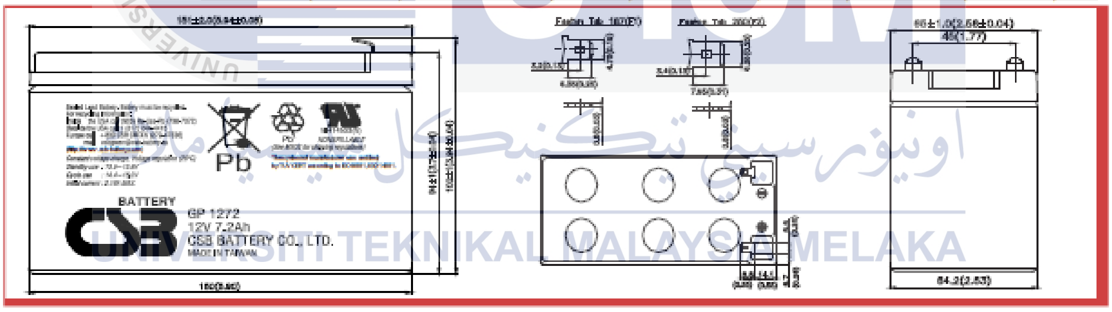
CSB-manufactured VRLA batteries are UL-recognized components under UL924 and UL1989.

CSB is also certified by ISO 9001 and ISO 14001.

▶ Dimensions :

Unit: mm (inch)

Overall Height (H)	Container height (h)	Length (L)	Width (W)
100±1 (3.94±0.04)	94±1 (3.7±0.04)	151±2 (5.94±0.08)	65±1 (2.56±0.04)



Constant Current Discharge Characteristics Unit:A (25℃,77°F)

F.V/Time	5MIN	10MIN	15MIN	30MIN	1HR	2HR	3HR	4HR	5HR	8HR	10HR	20HR
1.60V	35.6	22.0	16.5	9.61	5.51	3.08	2.14	1.65	1.35	0.925	0.778	0.456
1.67V	33.1	21.0	15.9	9.36	5.42	3.03	2.09	1.60	1.32	0.906	0.762	0.447
1.70V	31.9	20.5	15.6	9.24	5.37	3.00	2.06	1.58	1.30	0.897	0.756	0.438
1.75V	29.6	19.6	15.1	9.03	5.30	2.96	2.02	1.54	1.28	0.883	0.742	0.428
1.80V	27.2	18.6	14.4	8.77	5.23	2.92	1.99	1.50	1.25	0.871	0.732	0.421
1.85V	24.5	17.4	13.7	8.45	5.14	2.87	1.96	1.48	1.23	0.861	0.720	0.409

Constant Power Discharge Characteristics Unit:W (25℃,77°F)

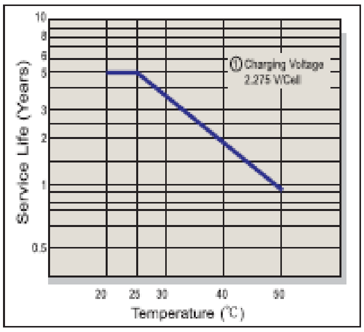
F.V/Time	5MIN	10MIN	15MIN	30MIN	1HR	2HR	3HR	4HR	5HR	8HR	10HR	20HR
1.60V	360	245	183	108	64.4	37.7	26.6	20.8	17.3	11.8	9.80	5.37
1.67V	340	235	177	106	63.6	37.1	26.3	20.5	17.0	11.6	9.69	5.27
1.70V	331	231	174	105	63.1	36.9	26.2	20.4	16.9	11.5	9.54	5.23
1.75V	313	222	170	103	62.4	36.4	25.9	20.2	16.7	11.4	9.48	5.15
1.80V	295	213	165	101	61.7	35.9	25.6	19.9	16.5	11.3	9.40	5.07
1.85V	276	202	158	99.0	60.8	35.4	25.2	19.6	16.3	11.2	9.29	4.99

RA: 1008

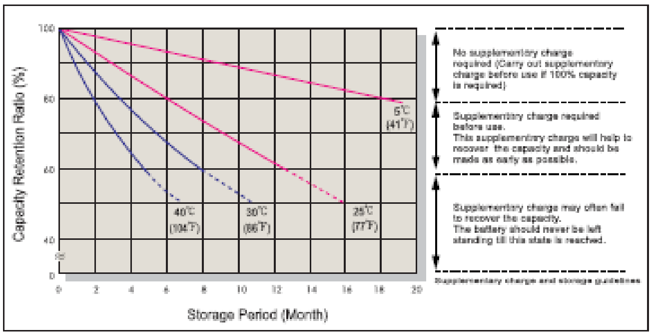
GP1272 12V 7.2Ah

CSB BATTERY

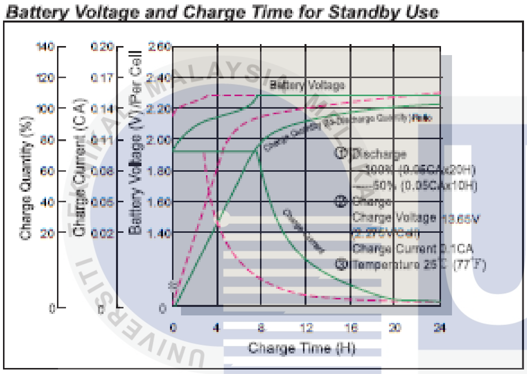
Trickle (or Float) Service Life



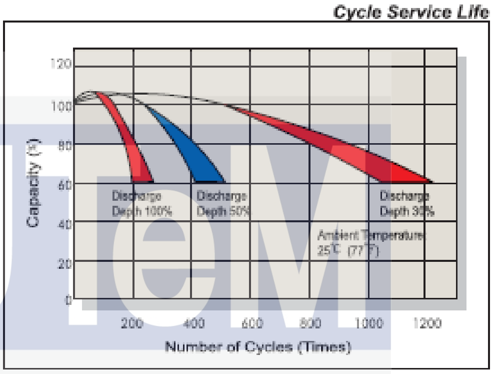
Capacity Retention Characteristic



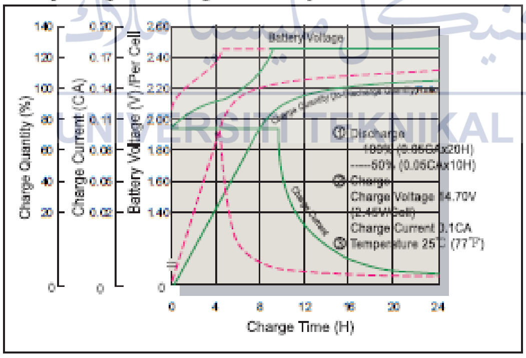
Battery Voltage and Charge Time for Standby Use



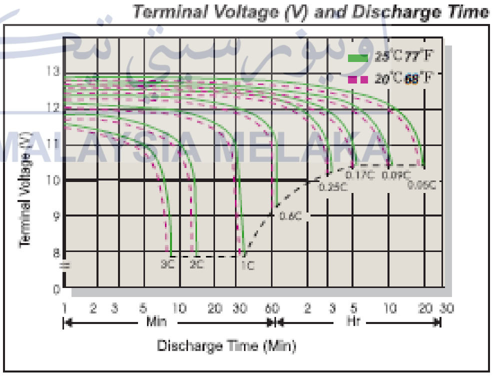
Cycle Service Life



Battery Voltage and Charge Time for Cycle Use



Terminal Voltage (V) and Discharge Time



Charging Procedures

Application	Charge Voltage(V/Cell)			Max.Charge Current
	Temperature	Set Point	Allowable Range	
Cycle Use	25℃(77℉)	2.45	2.40~2.50	0.3C
Standby	25℃(77℉)	2.275	2.25~2.30	

Discharge Current VS. Discharge Voltage

Final Discharge Voltage V/Cell	1.75	1.70	1.60	1.30
Discharge Current(A)	0.2C>(A)	0.2C<(A)<0.5C	0.5C<(A)<1.0C	(A)>1.0C

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APPENDIX C

Datasheet of battery 12V 100Ah

CSB

GP 121000

12V 100.0Ah

GP 121000 is a general purpose battery with 3-5 years in standby service or more than 260 cycles at 100% discharge in cycle service. As with all CSB batteries, all are rechargeable, highly efficient, leak proof and maintenance free.

Specification

Cells Per Unit	6
Voltage Per Unit	12
Capacity	100Ah @ 20hr-rate to 1.75V per cell @25℃(77℉)
Weight	Approx. 35kg(77.1 lbs)
Maximum Discharge Current	500A(5sec)
Internal Resistance	Approx. 7mΩ
Operating Temperature Range	Discharge: -20℃~50℃(-4℉~122℉) Charge: 0℃~40℃(32℉~104℉) Storage: -20℃~40℃(-4℉~104℉)
Nominal Operating Temperature Range	25℃±3℃(77℉±5℉)
Float Charging Voltage	13.5 to 13.8 VDC/unit Average at 25℃(77℉)
Recommended Maximum Charging Current Limit	30A
Equalization and Cycle Service	14.4 to 15.0 VDC/unit Average at 25℃(77℉)
Self Discharge	CSB Batteries can be stored for more than 6 months at 25℃(77℉). Please charge batteries before using. For higher temperatures the time interval will be shorter.
Terminal	Bolt & Nut
Container Material	Polypropylene(94-HB)

MH14533(N)

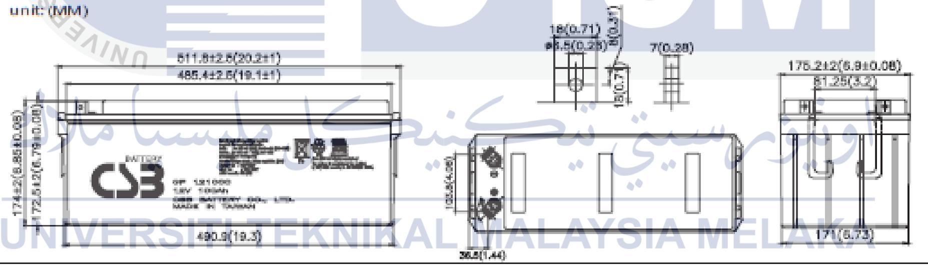
TÜV CERT ISO 9001

RWTÜV ISO 14001

CSB-manufactured batteries are UL-recognized components under UL924 and UL1989.
CSB is also certified by ISO 9001 and ISO 14001.

Dimensions

unit: (MM)



Constant Current Discharge Characteristics Unit:A (25℃,77℉)

F.V/Time	5MIN	10MIN	15MIN	30MIN	1HR	2HR	3HR	4HR	5HR	8HR	10HR	20HR
1.60V	388	253	193	119	71.4	42.0	29.8	23.4	19.3	12.6	10.3	5.37
1.67V	364	243	188	118	71.4	41.7	29.7	23.3	19.2	12.5	10.2	5.22
1.70V	353	238	186	118	71.3	41.6	29.7	23.3	19.2	12.5	10.2	5.16
1.75V	329	228	180	115	70.9	41.5	29.6	23.2	19.1	12.4	10.0	5.02
1.80V	305	217	173	113	70.5	41.5	29.6	23.2	19.0	12.3	9.83	4.87
1.85V	281	206	167	111	70.1	41.5	29.6	23.1	18.9	12.1	9.66	4.73

Constant Power Discharge Characteristics Unit:W (25℃,77℉)

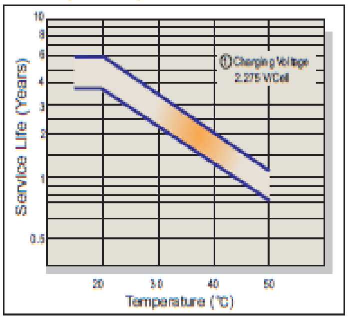
F.V/Time	5MIN	10MIN	15MIN	30MIN	1HR	2HR	3HR	4HR	5HR	8HR	10HR	20HR
1.60V	4650	3030	2320	1430	857	504	357	280	231	151	124	64.4
1.67V	4363	2911	2257	1416	856	501	356	279	230	150	123	62.7
1.70V	4340	2860	2230	1410	856	499	356	279	230	150	122	61.9
1.75V	3950	2730	2155	1385	851	499	356	279	229	149	120	60.2
1.80V	3660	2600	2080	1360	846	498	356	278	228	147	118	58.4
1.85V	3370	2470	2005	1335	841	498	356	278	227	146	116	56.7

- All mentioned values are average values.

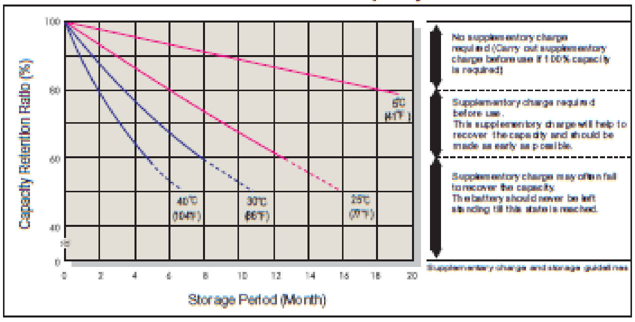
GP 121000 12V 100.0Ah

CSB

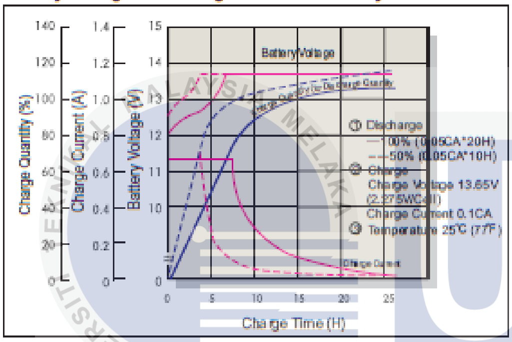
Trickle (or Float) Service Life



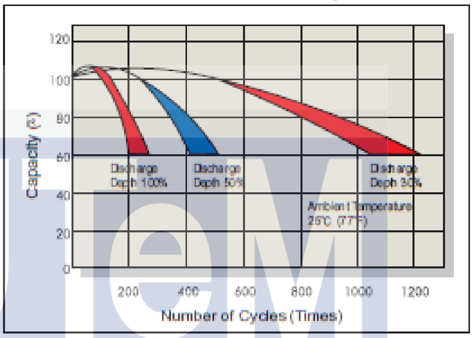
Capacity Retention Characteristic



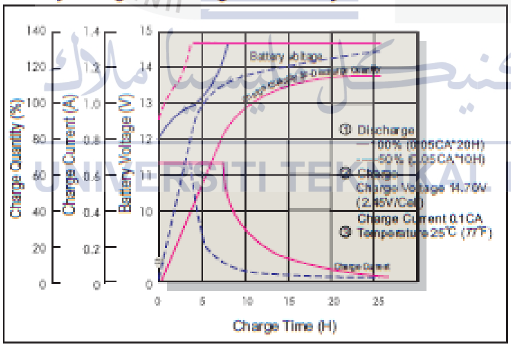
Battery Voltage and Charge Time for Standby Use



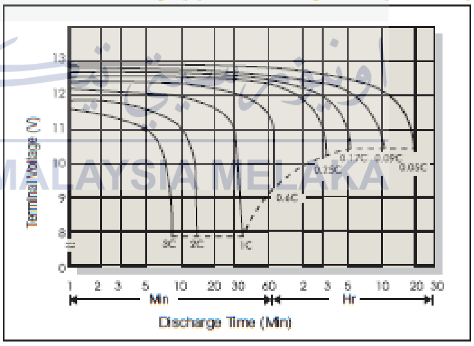
Cycle Service Life



Battery Voltage and Charge Time for Cycle Use



Terminal Voltage (V) and Discharge Time (25℃ 77℉)



Charging Procedures

Application	Charge Voltage (V/Cell)			Max. Charge Current
	Temperature	Set Point	Allowable Range	
Cycle Use	25℃ (77℉)	2.45	2.40~2.50	0.3C
Standby	25℃ (77℉)	2.275	2.25~2.30	

Discharge Current VS. Discharge Voltage

Final Discharge Voltage V/Cell	1.75	1.70	1.55	1.30
Discharge Current(A)	0.2C>(A)	0.2C<(A)<0.5C	0.5C<(A)<1.0C	(A)>1.0C

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0212g142000

APPENDIX D

Datasheet for Current Sensor

ACS756 *Fully Integrated, Hall Effect-Based Linear Current Sensor IC with 3 kVRMS Voltage Isolation and a Low-Resistance Current Conductor*

X050 PERFORMANCE CHARACTERISTICS over Range K[1]: T_{OP} = –40°C to 125°C, V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Primary Sampled Current	I_P		–50	–	50	A
Sensitivity	$Sens_{TA}$	Half scale of I_P applied for 5 ms, T_A = 25°C	–	40	–	mV/A
	$Sens_{TOP}$	Half scale of I_P applied for 5 ms	37.2	–	42.8	mV/A
Noise[2]	V_{NOISE}	T_A= 25°C, 10 nF on VIOUT pin to GND	–	10	–	mV
Nonlinearity	$E_{LIN(HT)}$	Up to full scale of I_P, I_P applied for 5 ms, T_{OP} = 25°C to 125°C	–1	–	1	%
	$E_{LIN(LT)}$	Up to full scale of I_P, I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–1.8	–	1.8	%
Electrical Offset Voltage[3]	$V_{OE(TA)}$	I_P = 0 A, T_A = 25°C	–	±2	–	mV
	$V_{OE(TOP)HT}$	I_P = 0 A, T_{OP} = 25°C to 125°C	–30	–	30	mV
	$V_{OE(TOP)LT}$	I_P = 0 A, T_{OP} = –40°C to 25°C	–60	–	60	mV
Total Output Error[4]	$E_{TOT(HT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = 25°C to 125°C	–7.5	–	7.5	%
	$E_{TOT(LT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–7.5	–	7.5	%

[1]Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_{OP}, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.
[2]6σ noise voltage.
[3]$V_{OE(TOP)}$ drift is referred to ideal V_{OE} = 2.5 V at 0 A.
[4]Percentage of I_P, with I_P = 25 A. Output filtered.

X050 PERFORMANCE CHARACTERISTICS over Range S[1]: T_{OP} = –20°C to 85°C, V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Primary Sampled Current	I_P		–50	–	50	A
Sensitivity	$Sens_{TA}$	Half scale of I_P applied for 5 ms, T_A = 25°C	–	40	–	mV/A
	$Sens_{TOP}$	Half scale of I_P applied for 5 ms	38.3	–	41.7	mV/A
Noise[2]	V_{NOISE}	T_A= 25°C, 10 nF on VIOUT pin to GND	–	10	–	mV
Nonlinearity	$E_{LIN(HT)}$	Up to full scale of I_P, I_P applied for 5 ms, T_{OP} = 25°C to 85°C	–1	–	1	%
	$E_{LIN(LT)}$	Up to full scale of I_P, I_P applied for 5 ms, T_{OP} = –20°C to 25°C	–1	–	1	%
Electrical Offset Voltage[3]	$V_{OE(TA)}$	I_P = 0 A, T_A = 25°C	–	±2	–	mV
	$V_{OE(TOP)HT}$	I_P = 0 A, T_{OP} = 25°C to 85°C	–30	–	30	mV
	$V_{OE(TOP)LT}$	I_P = 0 A, T_{OP} = –20°C to 25°C	–30	–	30	mV
Total Output Error[4]	$E_{TOT(HT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = 25°C to 85°C	–5	–	5	%
	$E_{TOT(LT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = –20°C to 25°C	–5	–	5	%

[1]Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_{OP}, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.
[2]6σ noise voltage.
[3]$V_{OE(TOP)}$ drift is referred to ideal V_{OE} = 2.5 V at 0 A.
[4]Percentage of I_P, with I_P = 25 A. Output filtered.

APPENDIX E

Percentage of Turnitin.

Turnitin Originality Report

Green Energy Management System by Nabilah Mat Kassim

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Hasan, Tawheed, Md. Faysal Nayan, Md. Asif Iqbal, and Monzurul Islam. "Smart Solar Home System with Safety Device Low Voltage Alert", 2012 UKSim 14th International Conference on Computer Modelling and Simulation, 2012.

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7 < 1% match (Internet from 15-Feb-2011)
http://www.mathworks.es/help/toolbox/physmod/powersys/ref/battery.html

8 < 1% match (Internet from 03-Dec-2006)
http://www.mcusky.com/sch/C0068.pdf

9 < 1% match (Internet from 01-Sep-2011)
http://danpritchard.com/wiki/Voltage_divider

APPENDIX F
Participation at I-ENVEX (2014)

certificate of Gold Prize

Engineering For Society

UniMAP

MINISTRY OF EDUCATION MALAYSIA

MOSTI

MINDS

ENVEX Young Researcher Club EYReC

SIRIM Quality Award

is presented to

HAZRIQ IZZUAN BIN JAAFAR; DR. ABDUL RAHIM BIN ABDULLAH; MOHAMAD FAIZAL BIN BAHAROM; NUR HAZAHSHA BINTI SHAMSUDIN; NURSABILLILAH BINTI MOHD ALI; NABILAH BINTI MAT KASSIM; RIZANALIAH BINTI KASIM; SHARIFAH YUSLINDA BT SYED HUSSIEN

for commending an excellent and creative effort to invent

GreEMys - Green Energy Management System

exhibited at the

INTERNATIONAL ENGINEERING INVENTION & INNOVATION EXHIBITION (i-ENVEX) 2014

held on

APRIL 11TH – 13TH, 2014
UNIVERSITI MALAYSIA PERLIS

Brig. Jen. Datuk Prof. Dr. Kamarudin Hussin
Vice Chancellor
Universiti Malaysia Perlis (UniMAP)

Academician Tan Sri Emeritus
Prof. Dr. Augustine S H Ong

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Engineering For Society

certificate of Participation

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Vice Chancellor
Universiti Malaysia Perlis (UniMAP)

Academician Tan Sri Emeritus
Prof. Dr. Augustine S H Ong

APPENDIX G

Participation at INNOFEST (2014)