CHAPTER 1

INTRODUCTION

1.1 Background of Study

The project is about constructing automatic battery monitoring system in photovoltaic application. It is one of components in photovoltaic system. A photovoltaic system used to harness solar energy to electricity; however, most photovoltaic system faces the problem of sustainability. In this country, solar radiation is available for 8 to 10 hours per day. There are also days where the solar radiation cannot be made available due to clouds or storm. Thus, the usage for storage is important in order to maintain the sustainability. In order for the battery to be working properly for the expected period, a monitoring system should be used so that the parameters of battery can be monitored: current, voltage and temperature. These are the 3 important parameters that should be controlled in order to prolong the lifetime of battery.

1.2 Problem Statement

In solar energy system, the issue of sustainability is the challenge. Furthermore, according to the graph of load mismatch, the load demand is inversely proportional to the solar radiation. During daytime (for 8 to 10 hours of solar), the solar radiation is high yet the load demand are less compared to nighttime where the situation are contradicted.

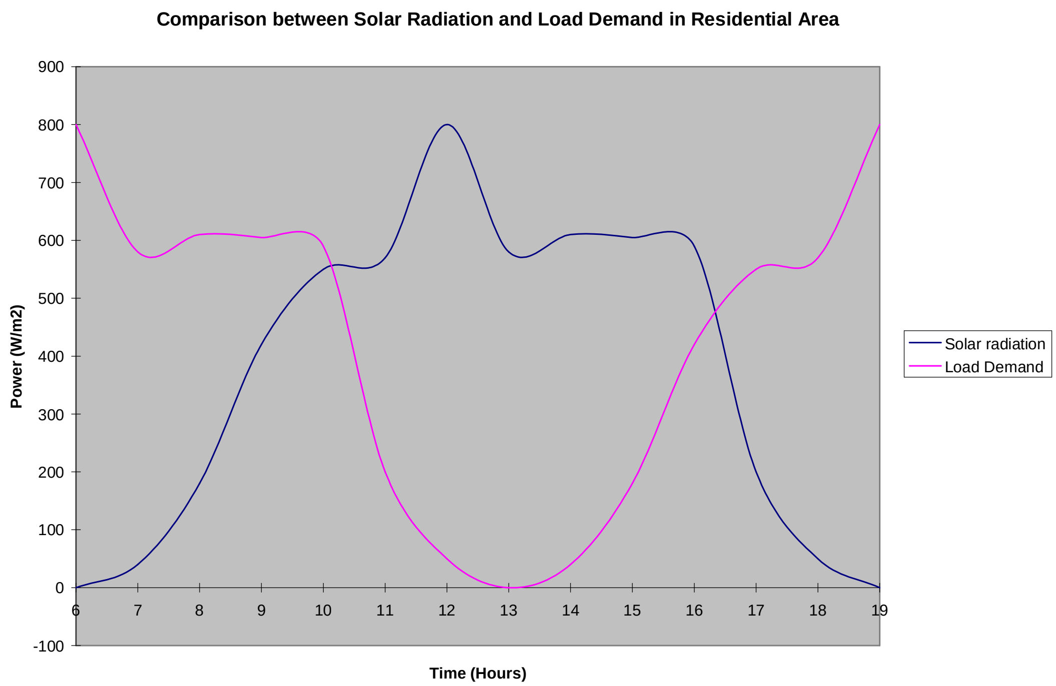

Figure 1: Comparison between Solar Radiation and Load Demand in Residential Area

That is why the storage for photovoltaic system is important and need to be maintained. The energy converted from solar radiation will be stored as much as possible into battery and it will be used at night when the solar radiation is not available.

1.3 Objectives

The objectives of this project are:

- to learn and study about solar geometry and ways to collect maximum solar radiation
- to identify mathematical models suitable for effective solar energy based battery charging system.
- to design the automatic battery monitoring system.

1.4 Scope of Study

The area of study for this project will be divided to 2 parts: the solar panel and the automatic battery monitoring system. For solar panel, it is crucial to understand the concept of solar geometry and PV sizing. The target user is in residential area, especially in rural area that faced difficulty in gaining reliable and continuous supply of Tenaga Nasional Berhad (TNB). The scope of study for solar panel covers for:

- Solar geometry
- The general consumption of standard minimum load in residential area
- The maximum voltage that a solar panel can converted from solar

For automatic BMS, it is needed to design an automatic monitoring system that links between battery units and the computer. Most study nowadays focuses on PV side, but the actual focus should be the storage. Due to that, the design for battery monitoring are supposed to analyzed automatically at any time needed and can be operated by people from limited engineering savvy. The study that needs to be covered is:

- The concept of automatic battery monitoring system
- The study of battery concept
- The purpose of charge controller circuit
- The suitable range of voltage for battery
- The suitable ambient temperature that can be maintain in order to protect the prolong of battery lifetime

CHAPTER 2

LITERATURE REVIEW

2.1 Solar Geometry

This automatic battery monitoring system is used in photovoltaic system. The photovoltaic system can provide cheap and clean electrical supply to residential area. Solar has been chosen as the industry is growing rapidly and being expected to be one of major alternative energy in future. It is important to understand that the solar radiation that has been emitting by sun will not be the same as what will be received in earth. The energy emitted from sun is called solar constant, G_{sc} which is received on a unit area of surface perpendicular to the direction of propagation of the radiation, at the earth's mean distance from the sun, outside the atmosphere. [1]

In solar geometry, it is important to know about solar movement concept and finding the best way to maximize solar radiation absorption. To understand the solar movement, the study about solar radiation which is regarding the variation of extraterrestrial radiation has been made. There are two sources of variation in extraterrestrial radiation that must be considered. The first source is the variation in the radiation emitted by the sun, while variation of the earth-sun distance, however does lead to variation of extraterrestrial radiation flux in the range of 3%. [1] This study of the sources is to show that the radiation from the solar will not be received exactly in earth due to transmission and atmosphere of earth. Thus, it is understandable that the calculated data is to be less than exact data. However, for calculation purposes, the energy emitted by the sun can be considered to be fixed for engineering purposes. [1]

Another important parameter that needs to be known is solar time. Solar time is the standardized time for all countries to locate sun. It is the time based on the apparent angular motion of the sun across the meridian observer. [1] This is because if the calculations and observations are made according to actual time, ambiguities will happen due to different longitude of each place. Solar time is very important in order to standardize the time between countries because the actual time will be differed for each country due to their longitudes position, while the solar time is same for all. The solar time has been calculated according to the longitude of Malaysia. Solar time will be applied only when the study of solar geometry is made further.

Another important parameter that needs to be considered in solar geometry study is the declination, which is the angular position of the sun at solar noon with respect to the plane of the equator where north will be positive. The angle of declination will be from $-23.45^{o} \leq$ declination $\leq 23.45\,^{o}$ [1]. The formula of the declination will be as in below:

$$Declination = 23.45 \sin e\left[360\left(284+n\right)/365\right]$$ --------------- (Equation 1)

The formula has been interpreted in order to discover the declination of sun so that this can ease the way to locate the sun in order to utilize maximum solar absorption of radiation. Each declination will differ each day per year. It is proven out that the range for declination angle is between 23.3^{o} to -23.4^{o} in Malaysia. This declination angle can be followed in order to track the sun for maximizing solar radiation absorption. The declination angle is used for calculation of solar geometry, together with the tilt angle of solar panel. This tilt angle is equal with the latitude of a place (e.g. tilt angle for Malaysia is 3^{o} which is also the latitude for the country).

All of this information of solar geometry is important in the project's next procedure in order to locate the correct orientation of sun for maximizing solar radiation. In this project, the solar tracking is not used; the focus is much more to learn tilt angle and concept of solar geometry.

2.2 Concept of Secondary Batteries

Battery comes in the part of storing the energy supply by the photovoltaic. Based on the survey that has been conducted, there are many types of battery that can be stored. It is a device that converts the chemical energy contained in its active materials directly into the electric energy by means of an electrochemical oxidation-reduction (redox) reaction. The characteristics are listed as below:

- The cells are sealed in variety ways to prevent leakage and dry out
- Some cells are provided with venting devices or other means to allow accumulated gases to escape [2]
- The advantage of using battery are:

    i. is the lightest
    ii. gives a high cell voltage and capacity[2]

The major components of battery consist of anode or negative electrode, cathode or positive electrode and electrolyte. Anode is the reducing or fuel electrode which gives up electrons to the external circuit and is oxidized during the electrochemical process. [2] There are 2 choices of anode which will be Hydrogen which is attractive material but got some means that reduces its electrochemical equivalence, zinc that is a predominant anode nowadays or Lithium which is the lightest metal. For cathode, it is the oxidizing electrode which accepts electrons from the external circuit and is reduced during the electrochemical reaction. [2] The choices of electrode can be either Oxygen or Metallic oxides. For electrolyte, its function is to provide the medium for transfer of electrons as ions inside the cell between the anode and cathode. [2] The choices of electrolytes will be either aqueous solution or non-aqueous solution.

The operation of a battery cell can be divided to two parts, which are discharging a battery and charging a battery. For discharging a battery, the negative electrode will be aniodic reaction (oxidation & loss of electrons) while the positive electrode will be cathodic reaction (reduction & gain of electrons). However, for charging a battery, the negative electrode will be cathodic reaction (reduction & gain of electrons) and positive electrode will be anodic reaction (oxidation & loss of electrons). The operations are shown as below:

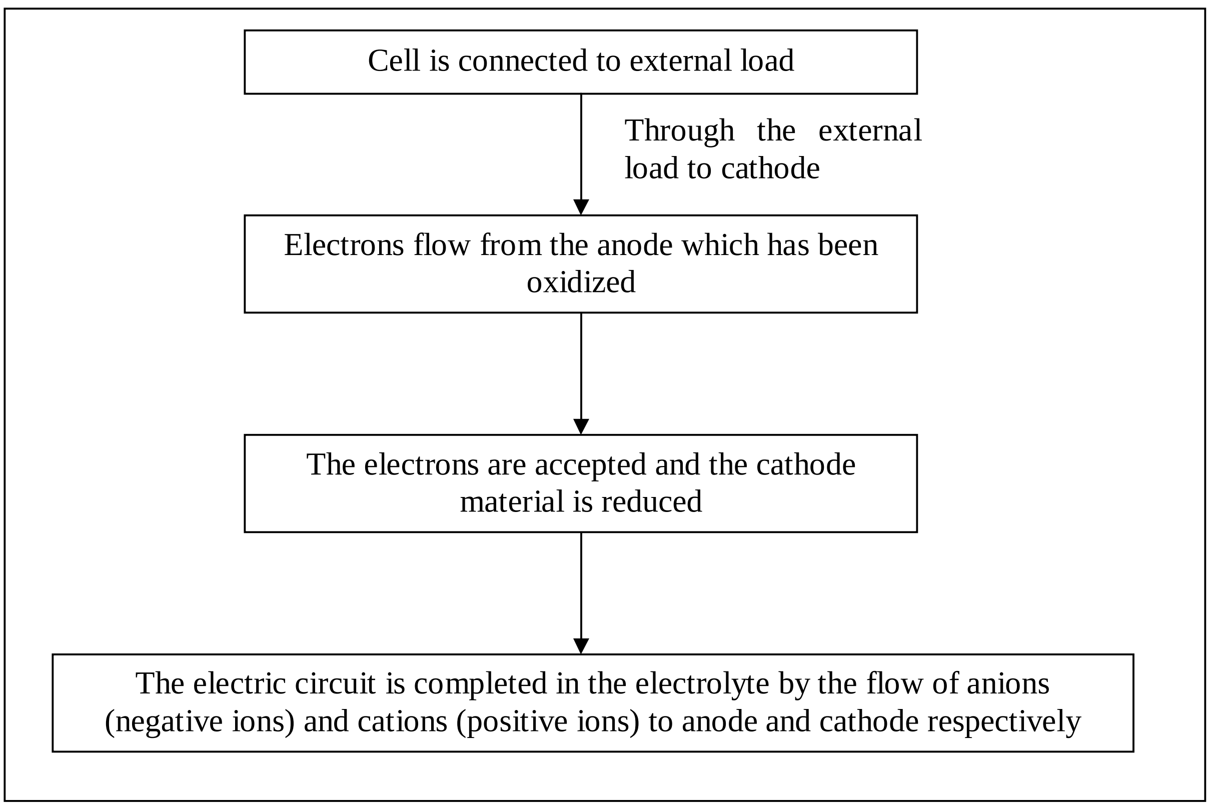

Figure 2: Discharging a battery [2]

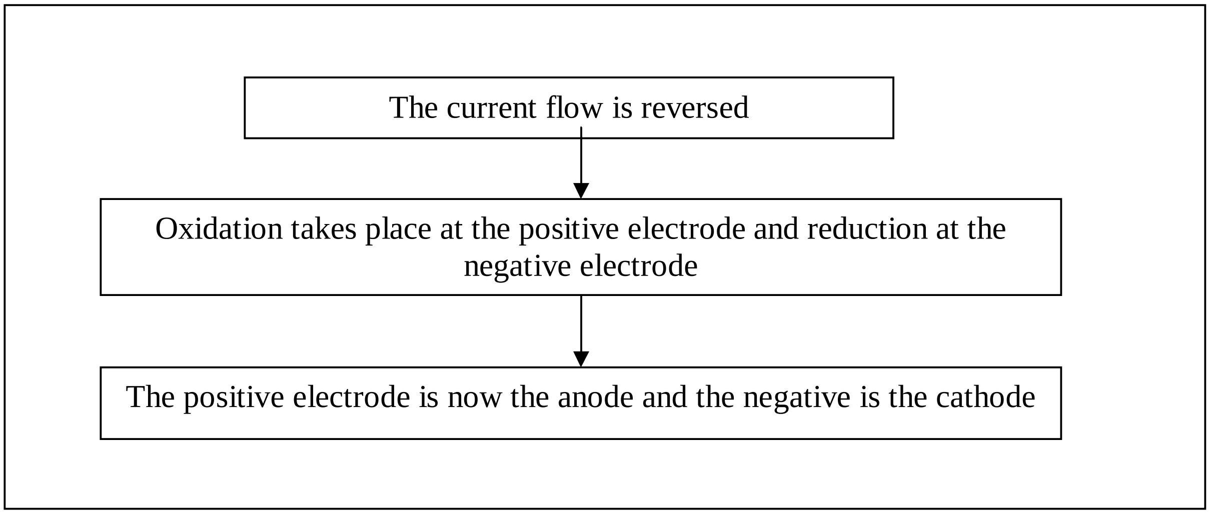

Figure 3: Charging a battery [2]

There are 3 types of batteries which are: primary, secondary and reserve battery. [2] The primary batteries are the battery that cannot be recharged, while secondary batteries are rechargeable. Reserve battery is the battery that only is used when it is really needed. The batteries that are used for solar applications are secondary battery as it can be rechargeable. After comparisons have been made, it is agreeable to use lead-acid battery due on the consideration of energy supplied, charging efficiency and economical aspect. Its usage has been widely used and the cost is considerable for this project. Due to that, more research will be focusing on the lead-acid battery. The details of comparisons between batteries will be shown in results and discussions section.

2.3 Concept of Automatic BMS in PV Application

The concept of this project is similar to the grid-combined solar-electric systems with battery backup. It incorporates batteries into the system as the backup for the grid-combined system used during blackout. The diagram for the whole system, combining with the grid-combined is as below:

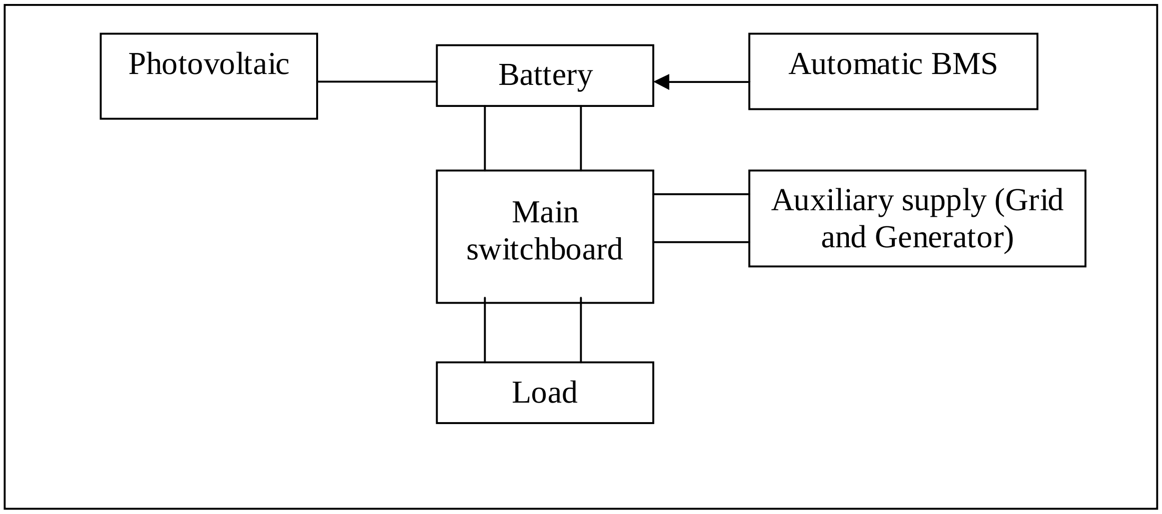

Figure 4: Grid-combined combined with battery and its automatic monitoring system in PV application

The project can also be used to save electricity usage from supplier. The supply from solar will be used during non-peak hour such as at the afternoon, while the peak hours such as at the night will be depending on the auxiliary supply. This is because after some research, it is quite impossible for the solar to be one of the main supplies to residential areas due to limited energy that can be converted by photovoltaic. Plus, it is very important to get the maximum and constant solar radiation. This is to ensure a constant supply to electrical appliances so that they will not be damaged by inconsistent supply. However, the availability of batteries as storage will help to reduce the electricity usage from auxiliary supply at night.

The basic tools that will be used are solar cells, charger controller and seal-lead acid battery. The prototype of this project will be scaled down from the exact size due to some limitation of solar panel. As for the relation between solar panel and battery with automatic Battery Monitoring System (BMS), the diagram is expected to be as below:

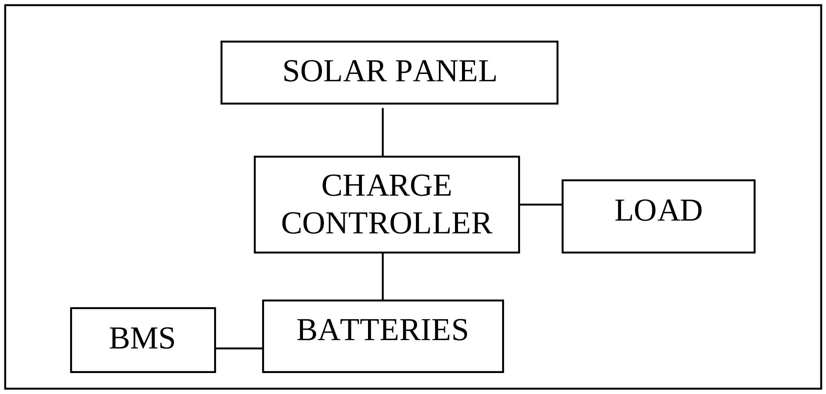

Figure 5: Solar panel connected to BMS and load alone

For battery monitoring parts, it covers about continuous monitoring of voltage, current, temperature and changes in order to pinpoint suspected error for individual batteries. This monitoring has strong relation with reliability as it is to ensure the lifetime of battery. Without the battery monitoring, the parameters for the battery will remains unknown. The need for automatic BMS rises because it gives accurate and automatic capture of data. It also shall provide an event log of all activities that relates with the battery bank if the circuit is about to be computerized. This system will also give alarm and notification (LED etc.) when the operating parameters exceed the default setting.

Before this, the battery monitoring system is conducted manually. This technique is done by measuring the voltage for each battery using voltmeter in every determined period (e.g. for every 3 months). The process is shown as in the figure 6:

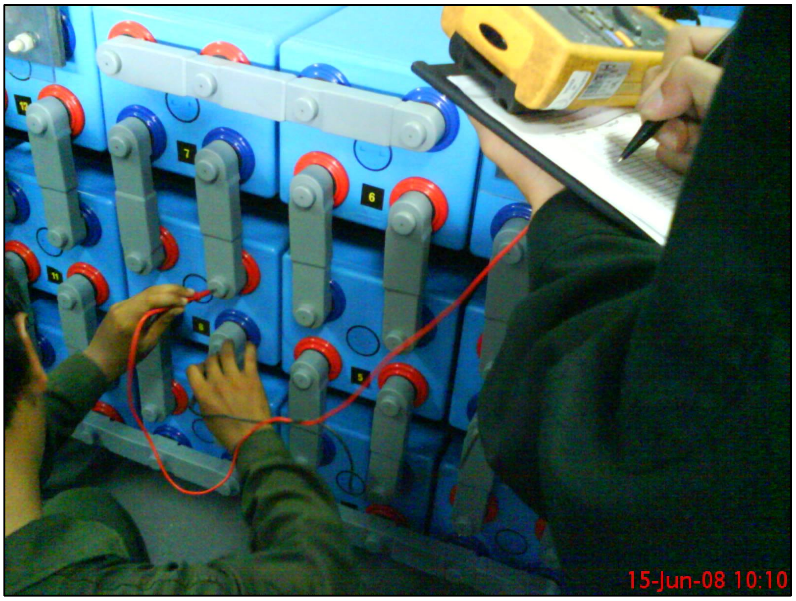

Figure 6: The monitoring process of battery manually

This method is prone mistakes and time consuming as in PV system, there will be hundreds of batteries needed, and human measurement is easily affected by surround factors such as parallax error.

The existed automatic battery monitoring system is used only in plant because it is very costly. Due to that, this new automatic BMS is very economical and cost-friendly. It saves cost not only in its construction, but it also saves cost especially in maintenance of battery. The lifetime of battery is extended and the cost of replacing new battery can be cut or save.

The diagram for computerized automatic battery monitoring system is expected to be as below:

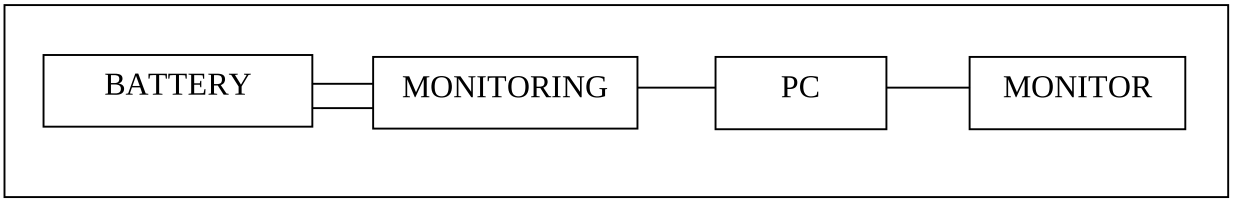

Figure 7: Computerized Automatic BMS [7]

The database that is expected to display will show the main activities such as overview of the status of battery (alarm status, current status, voltage status, and temperature status), alarms (temperature alarm, failure alarm, monitor voltage alarm, and current alarm) and report that contains the graph of overall system. [7]

This battery monitoring system shall detect any malfunction of battery by comparing the default value with current value of battery. If the current value exceeds the range of the default setting, then alarm will be on to inform user. For voltage monitoring, the point of measurements are positioned in parallel between 2 terminals of each battery, and there will also be measurement between positive terminal of first battery and negative terminal of last battery. [7] This is to measure the whole battery voltage. If alarm turns on, meaning there is problem regarding the whole battery.

For current measurement, the ammeter will be positioned in series with battery and the concept of monitoring will be as same as voltage monitoring. For temperature monitoring, a temperature sensor is positioned so that the wire that bring the current can go through the sensor. It is know that temperature depends on current, where if current increase, then temperature will also increase. However, the lead-acid battery can stand up to several Celsius before it gets damaged in extreme high temperature. The temperature is not only affected by the current flow, but also from surround heat. [7]

All these data will then be connected to interface that connect between hardware and software (computer). These data will then be processed and presented on the computer monitor.

The new automatic BMS that has been developed will take all these discussions for the consideration. This system has been developing to monitor the monitor the condition of battery used in photovoltaic application. Usual monitoring will be on battery low voltage, battery deep discharge and maximum number of days between full charging. [3] By taking certain criteria, the new system will consist of 3 circuits: the Voltage Indication Circuit, Temperature / Heat Alarm Circuit and Current Charging Indication Circuit.

For voltage indication circuit, a 12V sealed lead acid should be operated within 10.1V and 13.8V [3]. When the battery charges higher than 13.8V, it is said to be overcharge, and when it discharges below 10.1V it can be deeply discharge. A single event of overcharge or deep discharge can bring down the charge-holing capacity of a battery by 15 to 20 percent. [3]

As for Temperature / Heat Alarm Circuit, it has been acknowledged that battery lifetime depends on surround temperature, where it will decrease as the temperature increases. The ratio of battery lifetime and the surround temperature are shown as below:

Table 1: Ratio between surround temperature and expected battery lifetime [3]

Surround temperature (^{o}C)	**Expected battery lifetime (years)**
25	10
33	5
42	4

The condition of 25 ^{o}C is not possible as the ambient temperature in this country is 27 ^{o}C due to its tropical climates. This can be solved by putting the battery inside cooler place or by using air conditioner, yet this might lead to high expense. So the value of temperature around battery is expected to be controlled is 33 ^{o}C and the expected battery lifetime will be 5 years. If the temperature exceeds 33 ^{o}C, then the battery lifetime will be shortening.

By using this concept, a circuit has been developed. The important element of this circuit is the temperature sensor. There are three choices of temperature sensor: thermocouples, Resistance Temperature Detector (RTD) and thermistor. Even though the thermocouple is the most versatile transducer and PRTD is the most stable, yet thermistor remains as the largest parameter change with temperature as it is sensitive. [4] Thermistor got the negative temperature coefficient (NTC) characteristic where the value of resistor or voltage increase as temperature decreases. Plus thermistor is also cost effective.

For Current Charging Indication Circuit, the function is to show indication if the solar panel is charging the battery. It is indicated through an LED which will be on as the battery is being charged.

CHAPTER 3

METHODOLOGY

3.1 Project Identification

3.1.1 Project flow

For this project, it shall follow the methodology where it shows the each detailed activities and its expected duration to be completed. The project started with choosing the title and sketching the expected outcome based on current knowledge. This project has been divided to two parts; the research in solar geometry and research of automatic BMS. For solar geometry part, it involves in calculation of data in order to confirm the best location for placing solar panel.

However, for automatic BMS, comparison would be conducted between the expected outcome and existing design of BMS. Thus, after confirming the expected design (based on existing BMS design), the system of expected design will be developed and it will be tested through experimental work. After completing these parts, both of solar geometry knowledge and automatic BMS will be combined in one system. This system will then be simulated and prototype will be constructed from this system. Finally, the prototype will be tested and modify. The whole project flow can be seen as below:

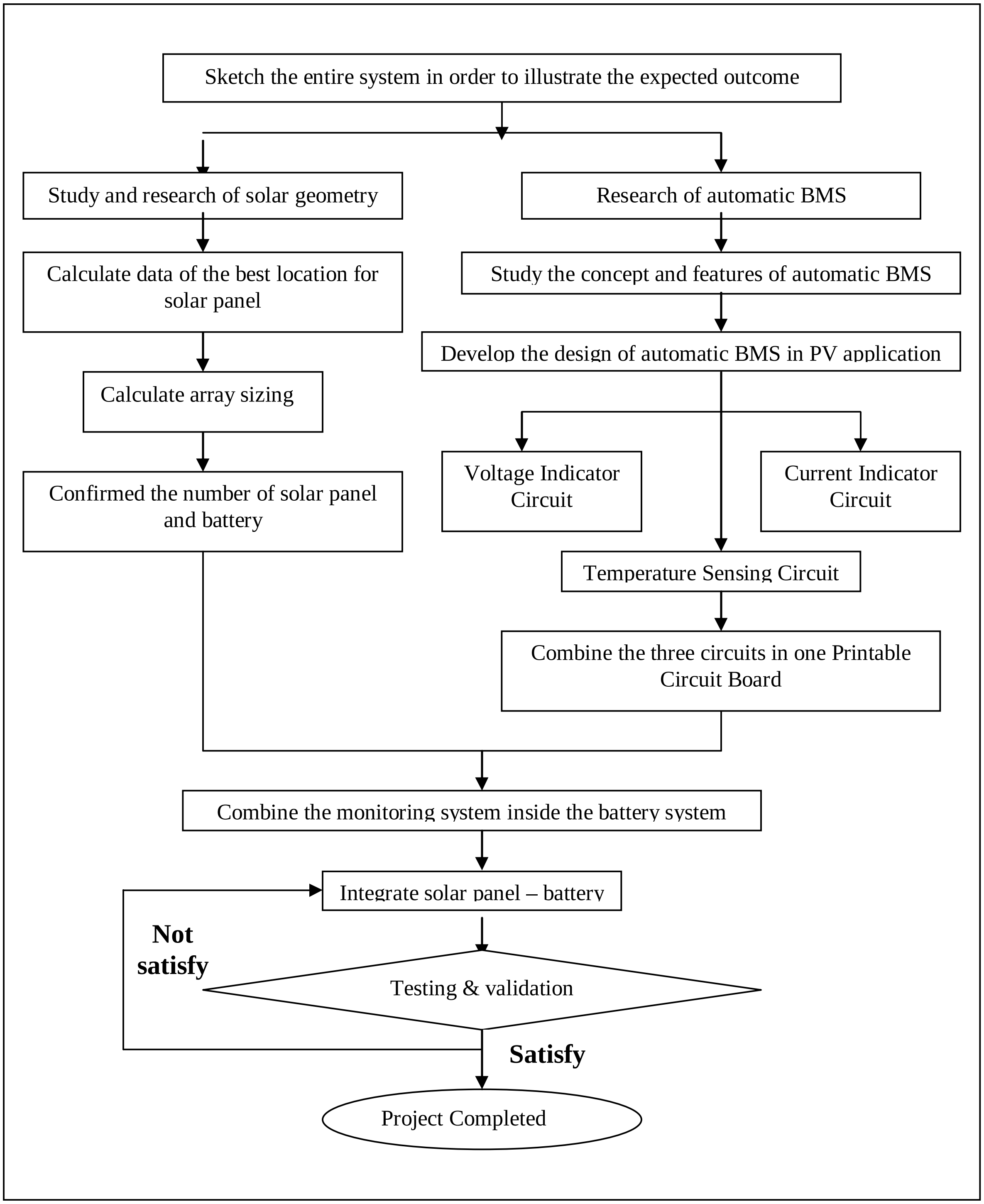

Figure 9: Project methodology and identification

3.1.2 Gantt Chart

So far, this project flows is according to the schedule. This project has completed the calculation, collecting and analyze data for the best location of solar panel, and this project now is in the researching for automatic BMS phase. For this project, the Gantt Chart is shown in the appendix section.

3.2 Tools Required

Tools required for this project consists of hardware. The tools are listed as below:

a) Solar cells
b) Charge Controller
c) Batteries (12V sealed-lead acid)
d) Voltage Indication Circuit
e) Charging Current Indication Circuit
f) Temperature / Heat Alarm Circuit

3.3 The Constructed Circuits of Battery Monitoring System

This circuit has been divided to 3 parts: the Voltage Indication Circuit, Charging Current Indication Circuit, and Temperature/ Heat Alarm. These 3 circuits are combined together in 1 Printable Circuit Board (PCB):

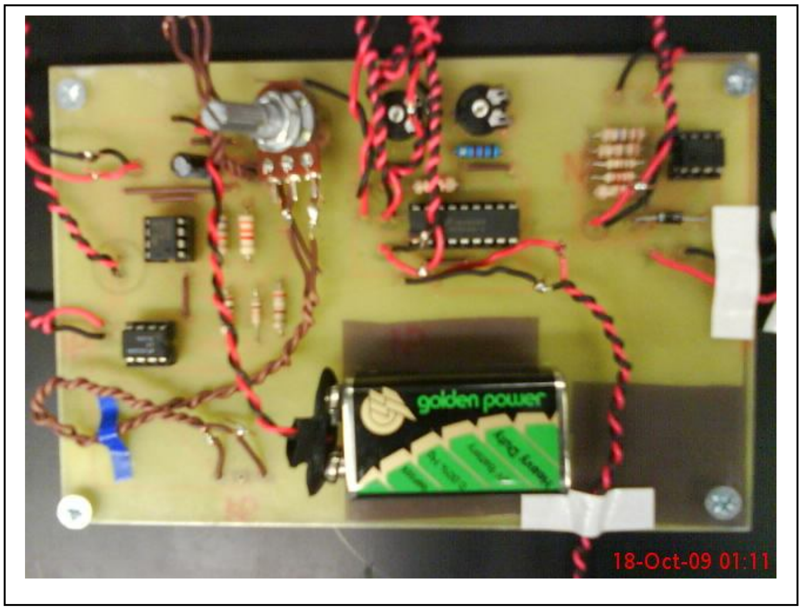

Figure 10: Circuits of Automatic BMS

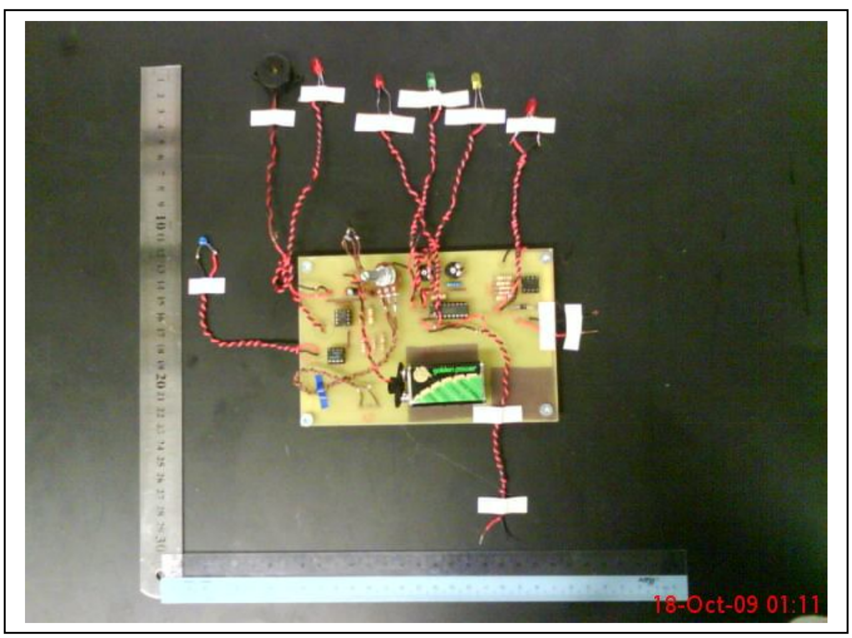

Figure 11: Automatic BMS on PCB

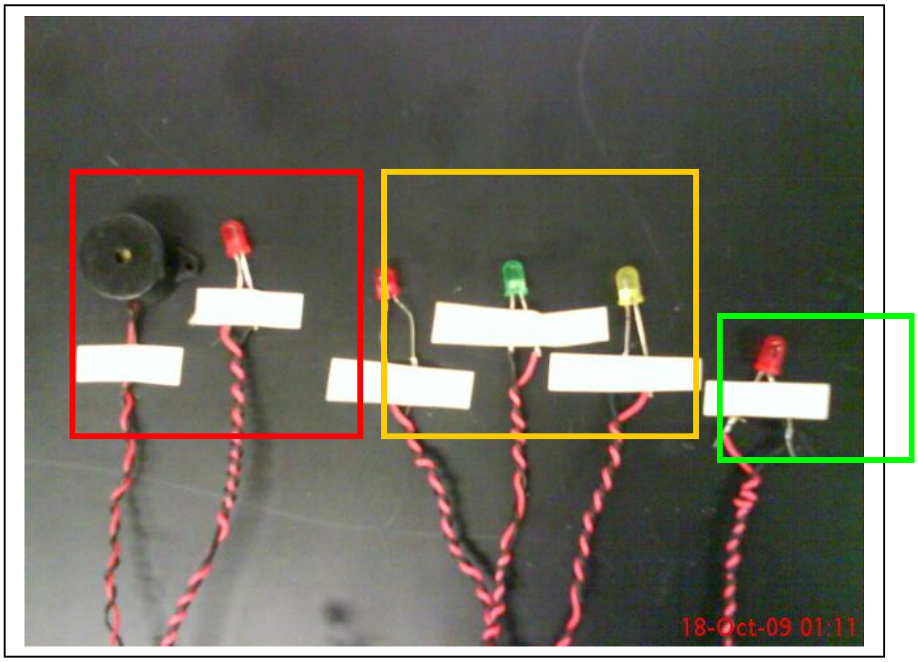

Figure 12: Output for automatic BMS (Red box for temperature circuit, Yellow box for Voltage Indication Circuit and Green Box for Current Indication Charging Circuit)

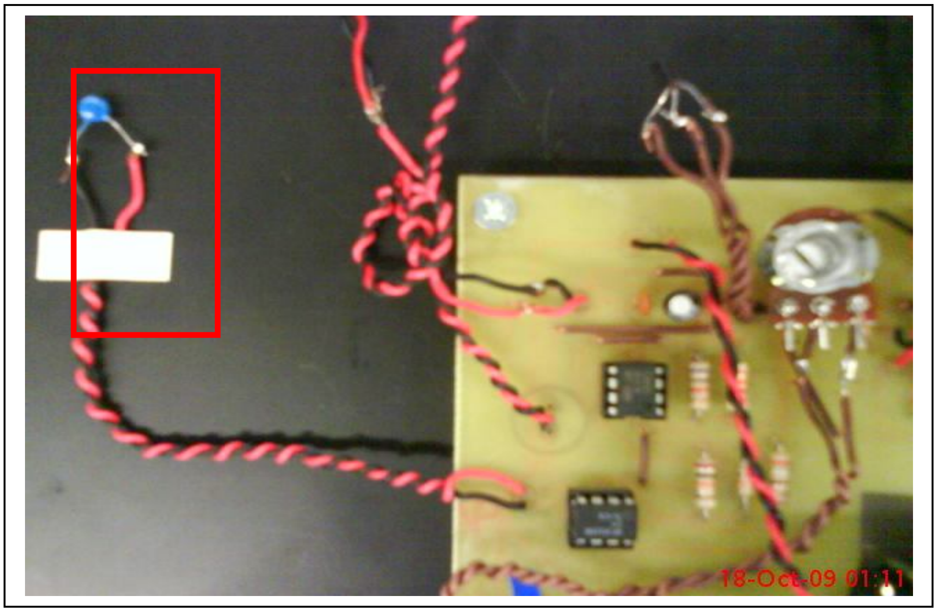

Figure 13: Temperature sensor (Thermistor)

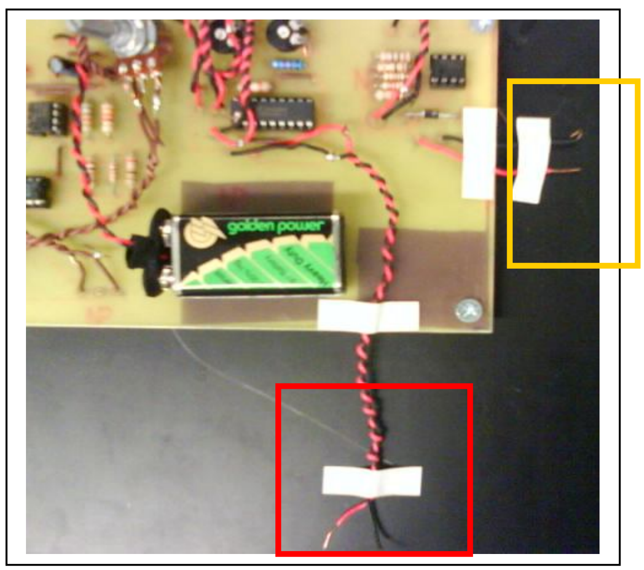

Figure 14: Battery Supply (Red Box) and Solar Panel (Yellow Box)

. All of these circuits has been integrated together in one Printable Circuit Board (PCB) and breadboard and has been tested with solar panel. The arrangement of the testing has been shown in Appendix E.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Study and Calculation for Load Demand and Automatic BMS Circuit

4.1.1 Experimental to measure energy supplied by solar panel

An experiment has been conducted in order to measure the voltage that can be supplied by a solar panel and to estimate the energy that it can supply. A 5.4cm x 5.4cm photovoltaic (solar light garden) is used and connected to a circuit which consists of Light-Emitting Diode (LED).

The diode is found to be on brightly. The voltage has been measured between the LED and it is found to be around 1.2V. Based on survey, it has been stated that for photovoltaic that can supply at least 1.2V, the current will be 60mA. Thus, the power that the small PV can supply is 0.072W

This power is expected to be supplied by the photovoltaic for 1 minute. The 5.4cm x 5.4cm can supply for 0.03 watt per day. This shows that more solar panel are needed to supply enough power to the system. PV sizing need to be conducted in order to find the accurate numbers of solar panels that are needed for this project.

4.1.2 Experiment to measure the battery discharging rate

Experiment has been conducted to investigate the characteristics of discharging battery supply. This is to prove the discharging curve for solar panel and to find the discharging rate of battery. The battery used is NiCad 1.2V, 2500mAh while the discharging load is LED 9V. The software used to measure the value: DataStudio. The charging circuit, connected with solar panel can be seen as the picture below:

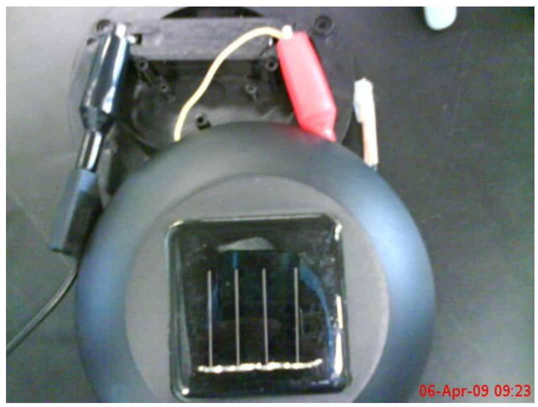

Figure 15: Charging circuit

Figure 16: Rechargeable battery 1.2V 2500mAh Ni-MH

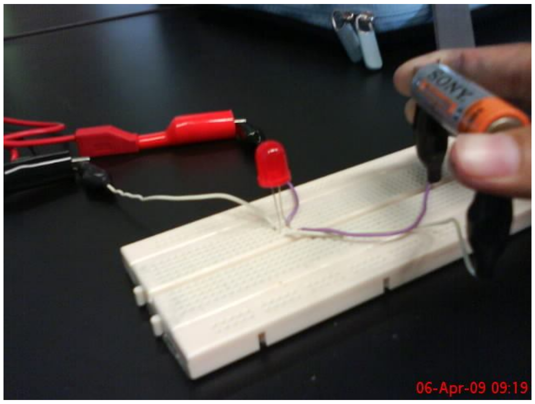

Figure 17: Discharging circuit

The result of the experiment can be seen in the graph below:

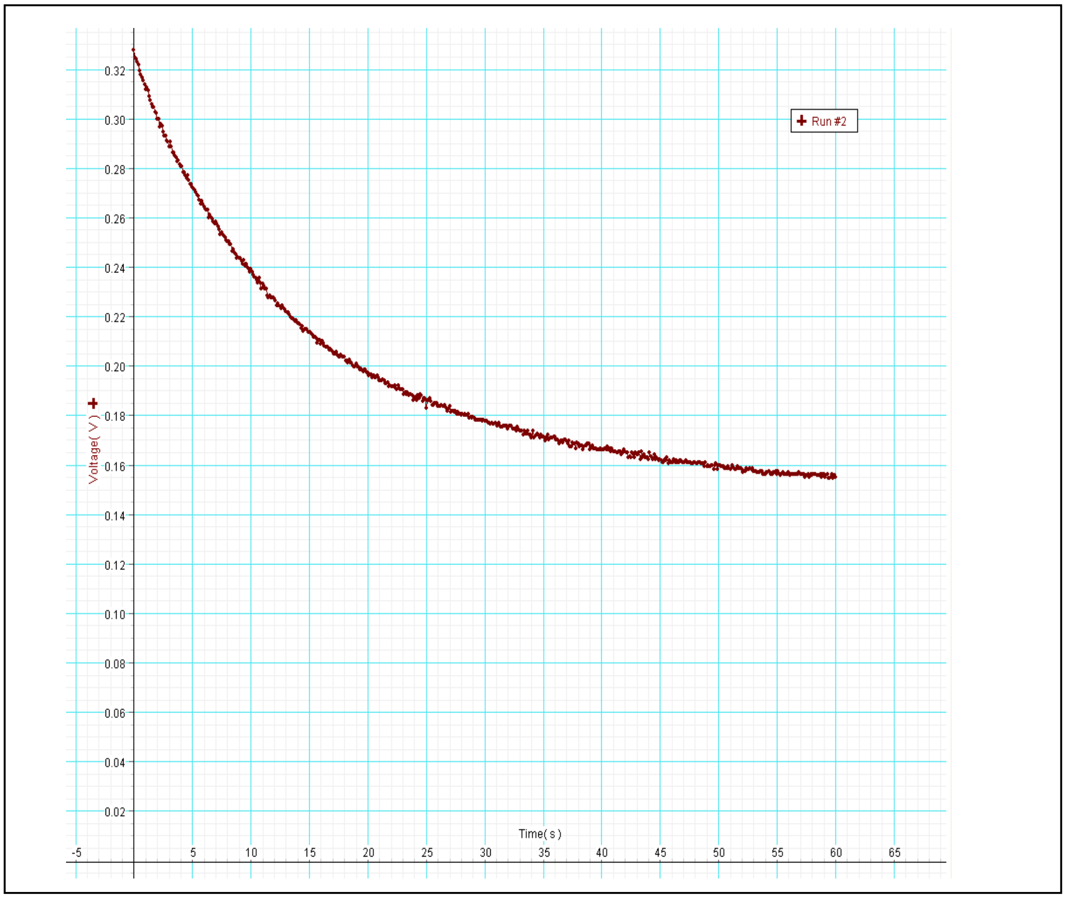

Figure 18: Discharging graph

The discharging rate is calculated to be 0.004V/s. This value shows that the discharging is very high, which raise a challenge on how to stabilize between the supply from solar and the discharging supply to load. Thus, one of the best way is to store as much as possible into the battery and this battery need to be maintain. Plus, the type of battery need to be investigates so that suitable type of battery can be used in the system. Also, the sizing of battery needs to be done so that the accurate sizing of battery can store supply that is enough for the load.

4.1.3 Calculation of average energy consumed

This section aims to calculate the load demand and PV sizing through averaging the energy consumed for residential in Malaysia. This has been done by surveying the monthly bill for 5 houses and finds the average of energy consumed. Below is the table that shows the survey that has been conducted in order to find the average energy consumed in residential area in 1 month. It is based on bill from Tenaga Nasional Berhad (TNB) which is the electrical supplier in Malaysia. The bills are attached in the appendix section. This survey covers for typical types of houses in Malaysia, such as terrace and squatter.

Table 2: Energy consumed for type of houses

Type of houses	**Energy consumed (KWh per month)**
Squatter	69
Terrace (1 storey)	367
Terrace (2 storey)	406
Semi detach (1 storey)	1209
Semi detach (2 storey)	1667
TOTAL	3718

The average energy consumed is:

$$Total / number\_of\_houses = 3718/5$$
$$Total / number\_of\_houses = 743.8KWh\_per\_month$$
$$Total / number\_of\_houses / day = 743.8KWh / 30 = 3099.2Wh\_per\_day$$

$$Wh = A * V * h$$
$$1\_house\_\sup plied\_by\_240V$$
$$Wh = A * 240 * h$$
$$3099.2 = A * 240 * h$$
$$Ah = 103.3$$

This has the conclusion that about 103.3 Amp-hour is consumed per day.

Using this value, the solar panel and battery sizing can be calculated:

a) Battery Sizing:

The calculation for daily amp-hour (for 1 house) is 103.3 Ah and the maximum days of autonomy have been taken as 3 days. [10] The depth of discharge for this sealed-lead acid is 20%. The multiplier factor in this calculation is 1.00. This multiplier factor is according to the lowest temperature the batteries will experience [11], thus the lowest temperature chosen for this calculation is 26.67^{o}C.

Table 3: Multiplier Factor for Battery Sizing [11]

Temperature (^{o}C)	**Multiplier**
26.67	1.00
21.11	1.04
15.56	1.11
10	1.19
4.44	1.30
-1.11	1.40
-6.67	1.59

Thus, the total battery capacity is 1549.5. The battery used for this system is MSB sealed-lead acid with rating of 12V, 7.2 Ah. The total batteries that will be used for this system is 432 where 216 will be connected in parallel while 2 lines of batteries are connected in series.

b) Array Sizing:

For this calculation, it is needed to multiply with 1.2 as the compensation loss from battery charge/ discharge. The average sun hours per day (for Malaysia) are 12. The optimum or peak ampere of solar module is 3 A. (based on type of solar module). Thus, the calculated solar modules should be 5 modules by paralleling 5 modules and 1 line series.

There are another way to calculate the energy demand and calculated PV sizing. This is by considering each possible and common electrical appliances used in 1 residential house. The procedures started by calculated all AC and DC loads, wattage and hours of use per week (Hrs/Wk), and again the same procedure in previous calculation are repeated here. The AC loads are listed as below:

Table 4: List of AC loads in residential area

Description of AC Loads Run by an Inverter	**Watts**	**Hours/Week**	**Watt hours/Week (Wh/Wk)**
Microwave	800	2	1600
Blow Dryer	1000	2	2000
TV/DVD 19"	40	28	1120
Clock Radio	1	168	168
Lights CF 20 watts x 6	100	40	4000
Washer	475	3.5	1662.5
Refrigerator	98	168	16464
Rice cooker	700	10.5	7350
Total Watt hours/Week (Wh/Wk)			34364.5

Most of electrical appliances use AC power supply but in reality, there are C devices that has built-in converters. The list of DC loads is as below:

Table 5: List of DC loads in residential area

Description of DC Loads	Watts	Hours/Week	Watt hours/Week (Wh/Wk)
Computer laptop	50	28	1400
Car player	15	42	630
Total Watt hours/Week (Wh/Wk)			2030

Then, the same calculation technique in previous calculation is repeated as follow:

a) Battery Sizing:

The daily amp-hour that has been calculated is 515.1 Ah where the maximum days of autonomy are 3 [11]. The depth of discharge for battery is 20% [11] and the Multiplier Factor is 1.00 [11]. The battery rating is 12 V, 7.2 Ah (MSB). Thus, the calculated battery capacity is 7726.3 Ah. The total batteries that will be used in the system are 2148 where the batteries in parallel are 1074 and 2 lines in series.

b) Array Sizing:

The compensation loss from battery charge/ discharge is set as 1.2 and the average sun hours per day (Malaysia) is 12 hours per day. The optimum or peak amp of solar module used is set as 3 A. Thus, the calculated total solar modules are 19 where 19 modules are arranged in parallel and in 1 line series.

However, the values obtained from second techniques (calculated PV sizing through summing up all the electricity appliances') are less accurate as types of electrical appliances' vary from 1 residential to another. However, both produce merely same load consumed which are around 103.3 Ah to 560.1 Ah. Thus, the first technique (calculated PV sizing by averaging housing load) is much more accurate and the results are considered for the next step in this project:

Total batteries used for this system: 432 (216 in parallel and 2 in series)
Total solar modules: 5 (5 in parallel and 1 in series)

4.1.4 Experiment to determine the resistance for PTC

This section focuses on how to deals with temperature / heat alarm circuit. Inside the circuit, thermistor is used. The concept of thermistor is like this: the value of resistor inside the thermistor changes due to the temperature change. For this circuit, the thermistor type used is Positive Temperature Coefficient (PTC) where the value of resistance decreases as the temperature increase. This is to make sure that the LED and speaker inside this circuit turn on when the temperature is high, in order to give alarm to user.

The circuit of temperature alarm circuit has been constructed like below:

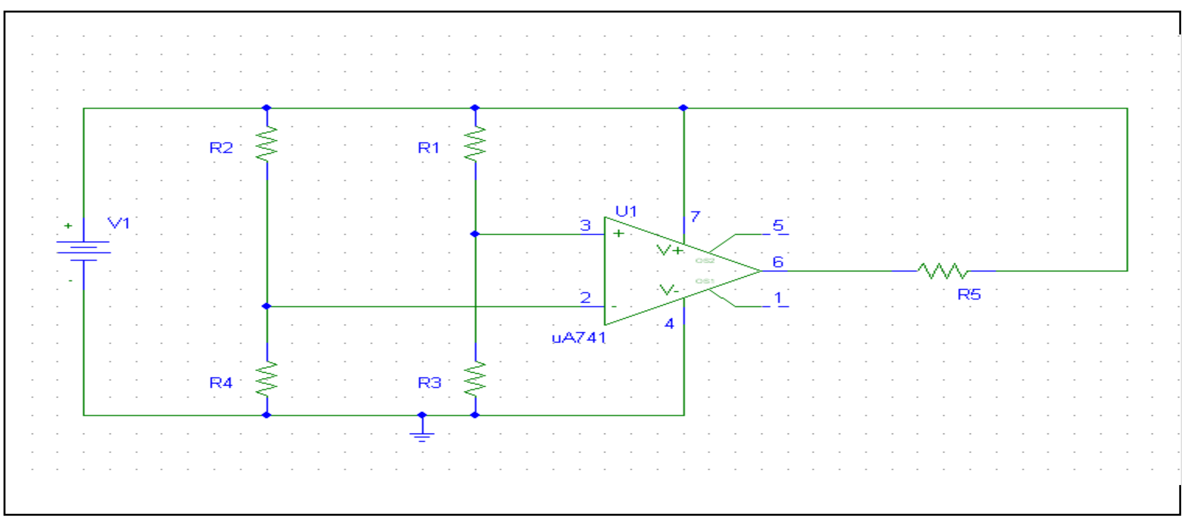

Figure 19: Temperature alarm circuit

This circuit is based on low cost fire alarm circuit. [5] Yet, it has been modified by including an operational amplifier (uA741) which functioned as voltage amplifier. R1 will be replaced by thermistor which acts as temperature sensor while R4 will influence the value of R1, meaning that R1 and R4 values will be the same. By doing this, the operational amplifier will be activated. To determine the value of R1, an experiment has been constructing by using the actual thermistor. Each thermistor has its own unique characteristic between temperature and resistance. It is to investigate the relation between thermistor resistance and ambient temperature. This is to set the value of R1 as the temperature should be around 33^{o}C. The experiment has been constructed like the diagram below:

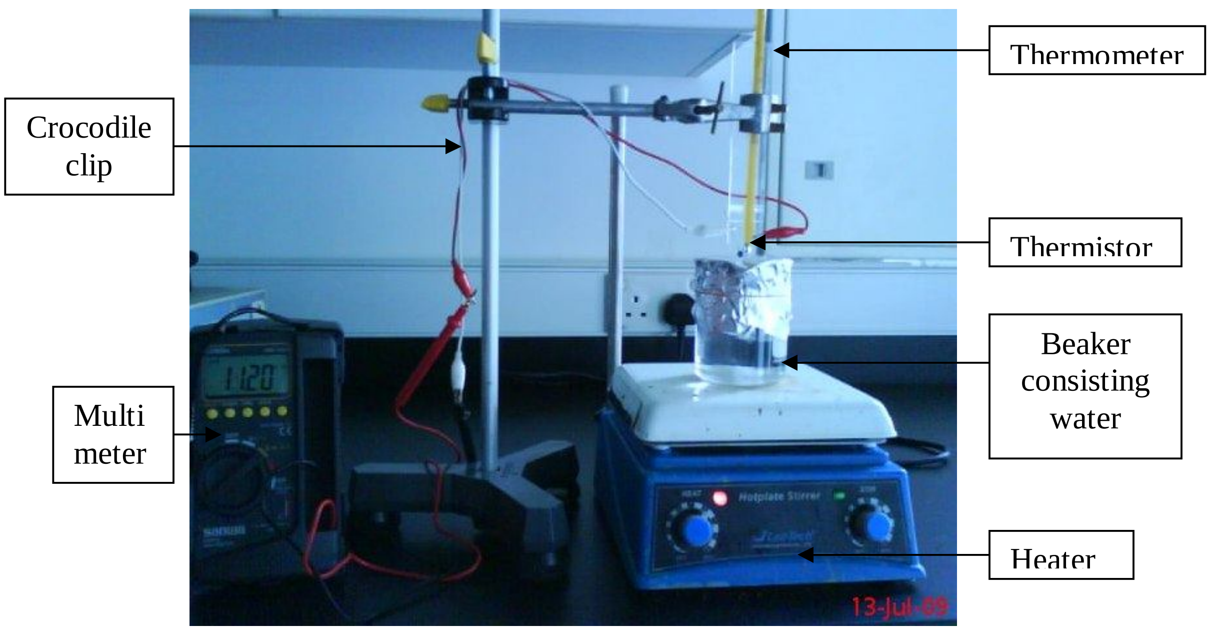

Figure 20: Experiment to determine the relation between thermistor resistance and ambient temperature

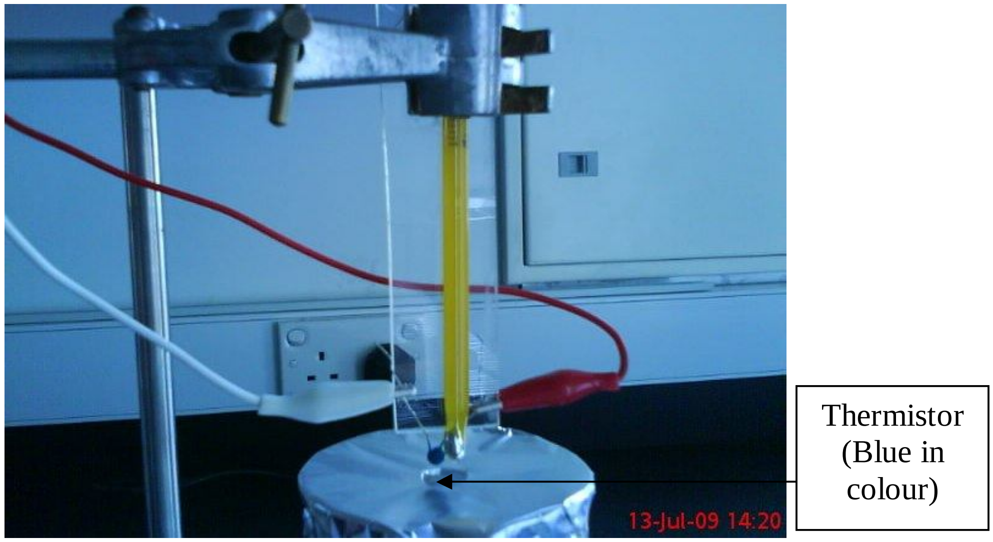

Figure 21: Clearer view of thermistor position

The experiment is conducted from 25°C to 90°C. The result of experiment is attached inside appendix. However, the significant part which is between 25°C to 40°C is shown as below:

Table 6: Result of experiment of relation between thermistor resistance and ambient temperature

Ambient temperature (^{o}C)	**Resistor of thermistor (ohm)**
25	12.35
26	11.30
27	11.20
28	10.80
29	10.20
30	9.50
31	9.20
32	8.80
33	8.60
34	8.20
35	8.17
36	7.55
37	7.25
38	6.70
39	6.50
40	6.30

Based on the table above, the resistance of thermistor is around 8.6 ohm when the ambient temperature is 33^{o}C. Thus, the value of R4 will be set to 8.6 ohm so that the thermistor value will be controlled to be 8.6 ohm in order to activate the operational amplifier.

4.2 Discussion

4.2.1 Type of Battery

For this project, secondary battery is compulsory for this project to store enough energy before it can be supply to consumers in order to prevent insufficient supply. For secondary battery, here are the types of battery:

a) Lead-acid battery
b) Lithium iron phosphate battery
c) Lithium Sulfur Battery
d) Lithium-ion polymer battery
e) Nickel Hydrogen Battery
f) Nickel-cadmium Battery
g) Nickel-metal hydride Battery
h) Nickel-iron battery
i) Rechargeable alkaline battery
j) Sodium-sulfur Battery
k) Vanadium redox Battery

The comparisons have been made between the commonly used battery, and the result can be seen from the table below:

Table 7: Comparisons between Secondary Batteries [6]

Type of battery	**Lead-acid battery**	**Lithium-ion polymer battery**	**Nickel-cadmium Battery**	**Nickel-metal hydride Battery**	**Nickel-iron battery**
Energy/weight (Wh/kg)	30-40	130–200	40–60	30–80	50
Energy/size (Wh/L)	60-75	300	50–150	140–300	100
Charge/discharge efficiency	50%-92%	99.8%	70%–90%	66%	65%
Self-discharge rate (permonth)	3%-20%	5%	10%	30%	20%-40%
Nominal Cell Voltage (V)	2.105	3.7	1.24	1.2	1.2

Based on the table, the lithium-ion polymer battery has the best characteristics while the nickel-iron battery has the weakest characteristics between all of the batteries. However, comparing on other factors such as cost effectiveness and availability, sealed-acid battery is the best choice as it has moderate characteristics compared to other batteries. Its usage has been widely used and the cost is considerable for FYP project. Due to that, more research will be focusing on the lead-acid battery.

4.2.2 *Circuits of Battery Monitoring System (BMS)*

For this chapter, brief description is given for each of the 3 circuits: the voltage indication circuit, charging current indication circuit and temperature/ heat alarm circuit.

4.2.2.1 Voltage Indication Circuit

For this project, the concept of monitoring voltage, current and temperature will be taken but the prototype will be built in terms of circuitry. The concept is to compare between the default setting with actual value of voltage, current and temperature. Any mismatch that exceeds the range will cause the alarm to be turned on. This range value will be getting from experiment. The experiment is conducted using comparator, where the value of battery is compared with supply. The comparator used is LM393, where the schematic is as shown in the figure below:

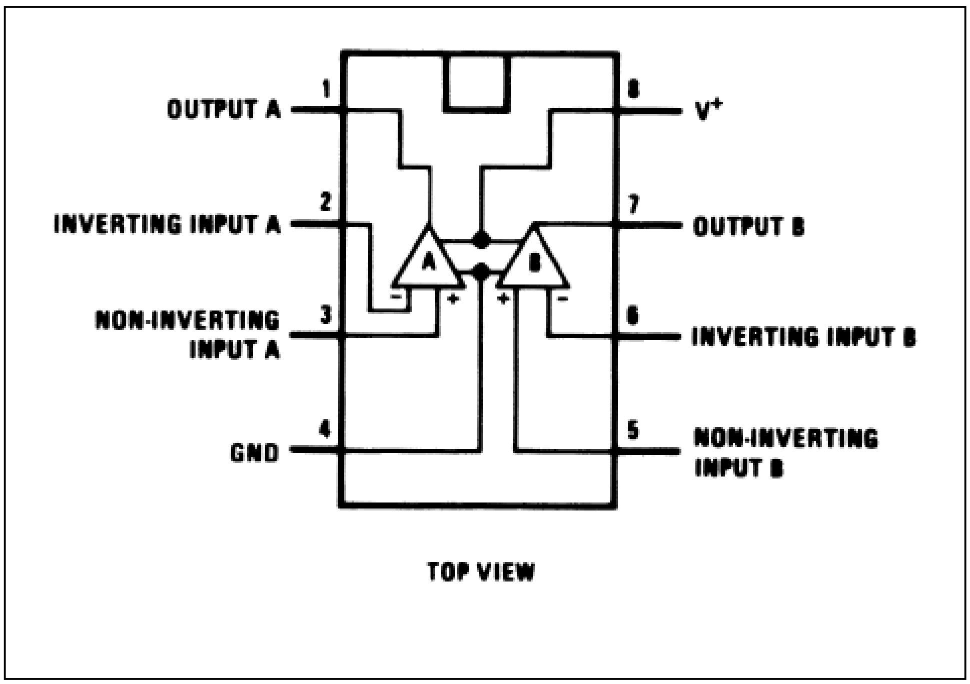

Figure 22: Schematic of LM393

The supply will vary while the value of battery is fixed. The output of be in 2 fixed values. The maximum voltage that the LM393 can stands is 36V, but the output voltage shows the value of 1.5V only when the supply voltage is vary between 7.5V and 14.9V. Outside this range, the output voltage shows constant value of 1.3V. This means that, the range is only from 7.5 to 14.9V. Apart from that, the alarm will be on. The full result is shown in the table below:

Table 8: Output voltage for comparator LM393

Supply voltage, V_{varies}	**Battery voltage, $V_{reference}$**	**Output voltage, V_{out}**
1.0	12.0	1.3
2.0	12.0	1.3
3.0	12.0	1.3
4.0	12.0	1.3
5.0	12.0	1.3
6.0	12.0	1.3
7.0	12.0	1.3
8.0	12.0	1.5
9.0	12.0	1.5
10.0	12.0	1.5
11.0	12.0	1.5
12.0	12.0	1.5
13.0	12.0	1.5
14.0	12.0	1.5
15.0	12.0	1.3
16.0	12.0	1.3
17.0	12.0	1.3
18.0	12.0	1.3
19.0	12.0	1.3
20.0	12.0	1.3

Due to that, the output to alarm system will be 1 (on) when the value of voltage reach approximately 7.5V until 14.9V.

The concept of comparator circuit is expected to be as below:

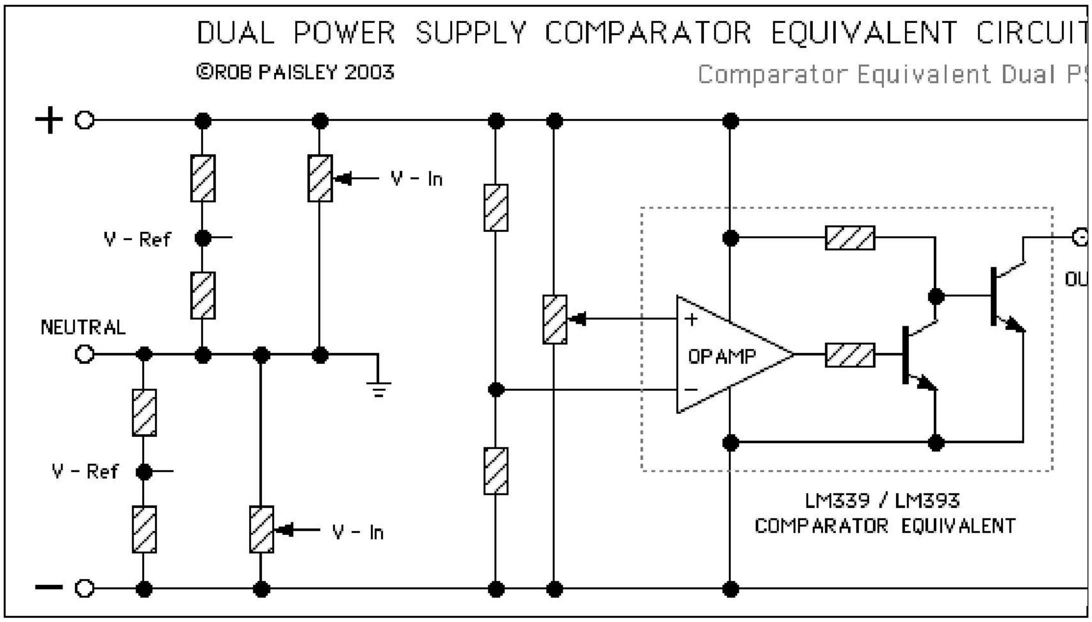

Figure 23: Comparator circuit schematic [8]

Another alternative is the voltage indicator circuit. This circuit has been constructed, and it functioned well as it can indicate the voltage of battery automatically. The value of supply can be measured and indicated by using LEDs just like the diagram below:

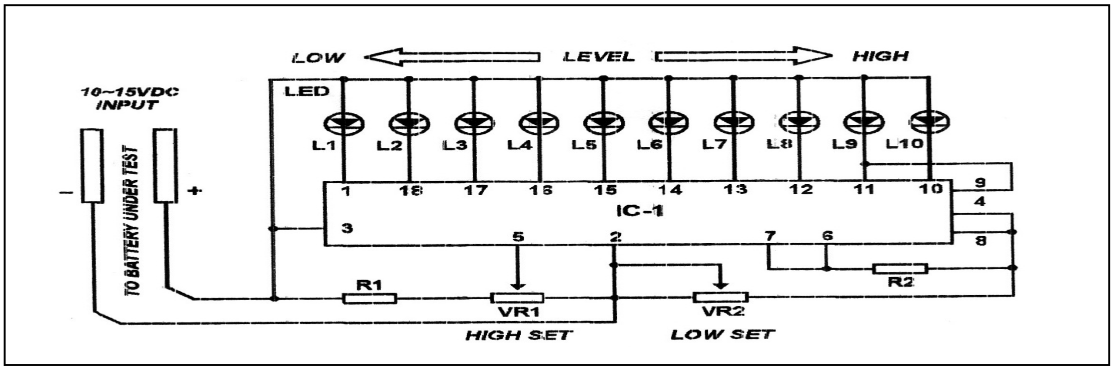

Figure 24: Voltage indication circuit

After comparing both of the 2 alternatives, the voltage indication circuit has been chosen due to its larger voltage range and better accuracy. As what has been discussed before, the 12V sealed lead acid battery should be operated within 10.1V and 13.8V [3]. Thus, the circuit has been modified where the 10 LED's has been simplified to just 3 LED's. Each LED shows its own indication; the first LED is to show if the voltage is less than 10.1V (undervoltage); second LED indicates 10.1V – 13.8 V (normal voltage); and finally third LED indicates more than 13.8V (Overvoltage). The new modified circuit is as below:

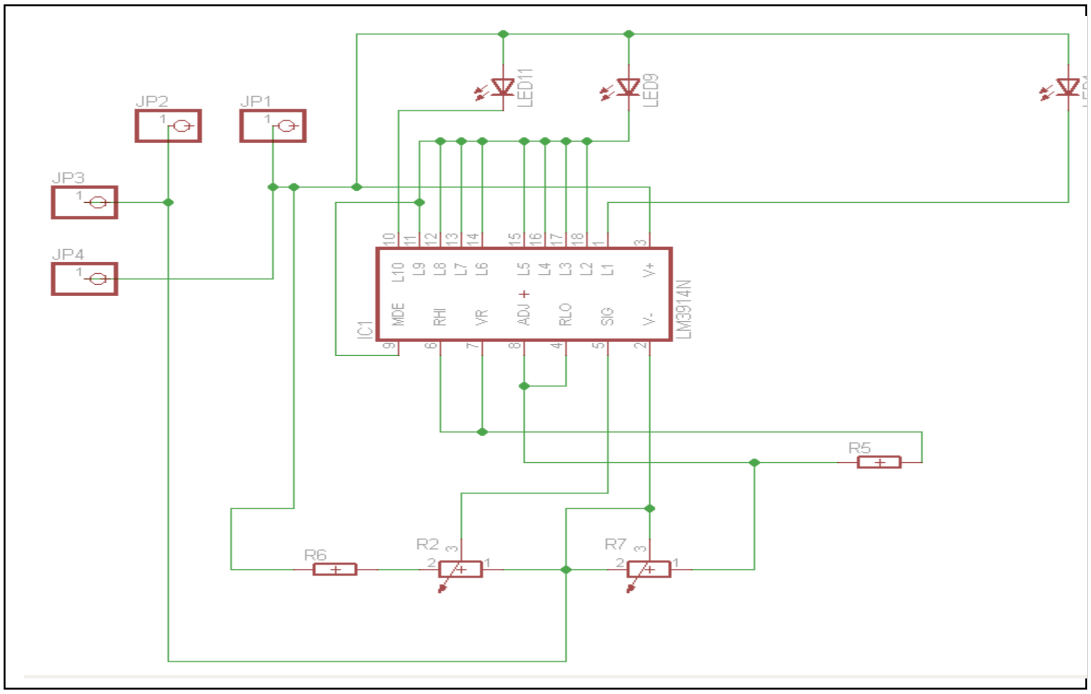

Figure 25: Modified Voltage Indicator Circuit

This circuit has been tested and has been clarified. The experiment is shown under Appendix F.

4.2.2.2 Charging current Indication Circuit

*T*he minimum current of charging 12V sealed lead acid battery is 25mA and the maximum current is 1A before it can damage the circuit. Thus, the value of resistors has been adjusted so that the LED (D2) will turn on when the battery is charging. The LED will be as indication if the solar panel is charging the battery. The full circuit of current charging circuit is as shown as below:

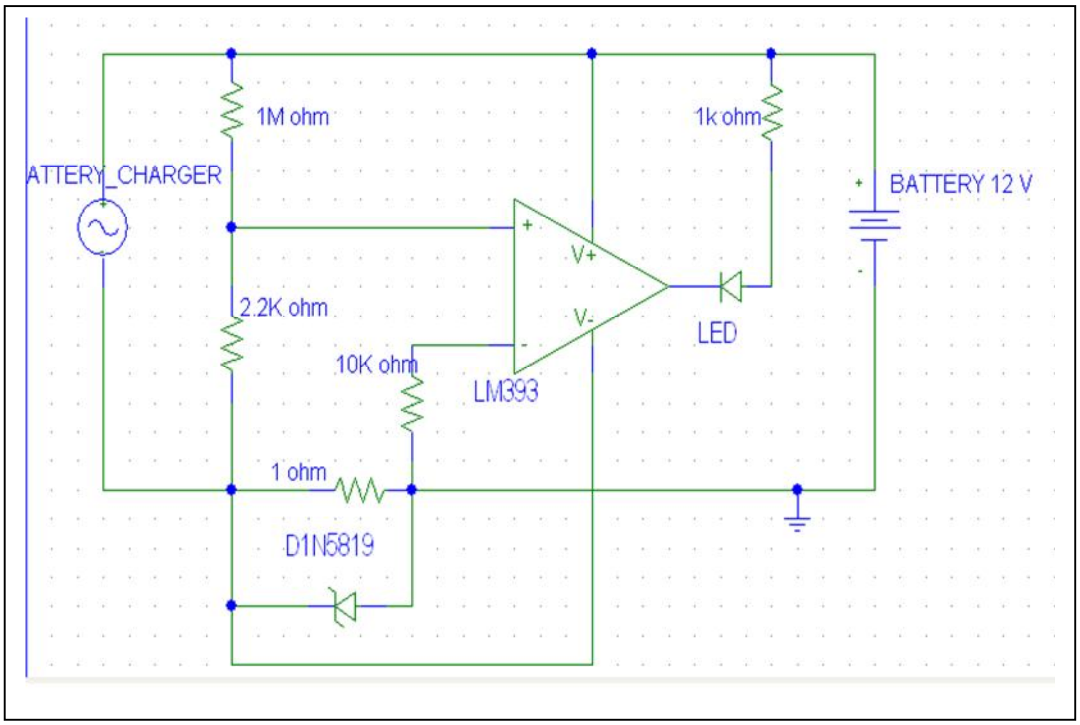

Figure 26: Charging Current Circuit [9]

4.2.2.3 Temperature / Heat Alarm Circuit

Based on information from PTC experiment, the circuit is modified as below:

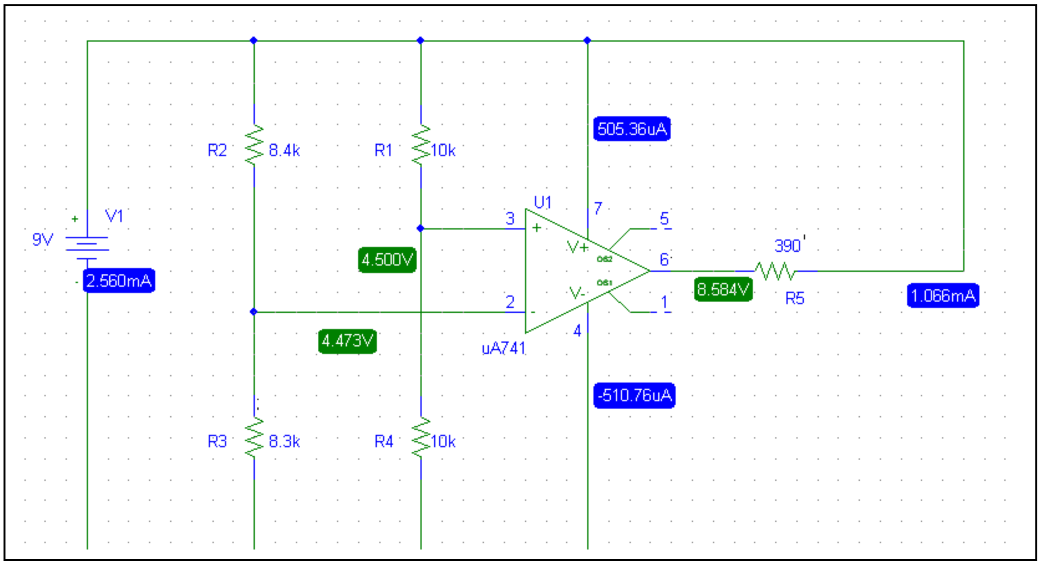

Figure 27: The modified circuit with its outcome

The output is found to be 8.584V and the current is 1.066mA, which is much enough to drive a 2V Light emitted diode (LED). Plus it is also enough to drive a speaker (for alarm) by using PNP transistor. The whole actual circuit has been constructing as below:

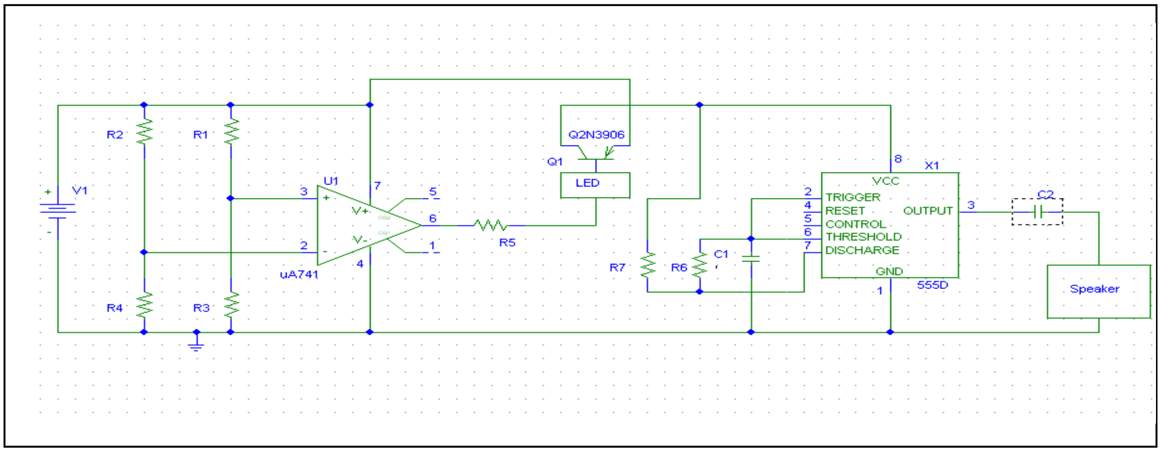

Figure 28: The Temperature / Heat Alarm

4.2.3 Cost calculation for automatic BMS

One important advantage of this innovated automatic BMS is its cost which is cheap. Usual PV system is very costly, especially its solar module. Thus, it is vital to reduce as much cost as possible in other elements in PV system. The total cost for the project is calculated based mainly on the cost for each electronic components, plus with other miscellaneous cost (e.g. cost for making up the casing for the circuit. The casing is shown under Appendix D). The electronic components are summed up like the table below:

Table 9: Electronics Components Cost

Circuit	Electronic Components	Quantity	Price per component	Total Price
Voltage Indication Circuit	IC LM3914	1	RM 5.30	RM 5.30
	Resistor	2	RM 0.45	RM 0.90
	Variable resistor	2	RM 0.90	RM 1.80
Current Indication Circuit	IC LM393	1	RM1.60	RM1.60
	Resistor	5	RM 0.05	RM 0.25
	Light Emitted Diode (LED)	1	RM 0.10	RM 0.10
	Diode IN5819	2	RM 0.30	RM 0.60
Temperature/ Heat Alarm Heat	Thermistor (NTC)	1	RM 3.00	RM 3.00
	Variable Resistor	2	RM 0.90	RM 1.80
	Resistor	5	RM 0.45	RM 2.25
	IC LM741	1	RM 1.60	RM 1.60
	IC LM555	1	RM 0.50	RM 0.50
	Capacitor	2	RM 0.30	RM 0.60
	Speaker	1	RM 1.90	RM 1.90
Total Cost				RM 22.20

Other miscellaneous cost: Casing cost = RM 18.00

Total project cost = Electronic cost + Miscellaneous cost = RM 32.20

From the calculation, it is obvious that the innovated automatic BMS is much cheaper than the existed system. Thus, it made possible for each residential to install this system economically. The whole cost can now be concentrated only on solar module.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This project has covered various works of study. Starting for the part of solar geometry, followed by concept of secondary batteries, type of secondary battery, the concept of automatic BMS, the voltage indication circuit, current charging indication circuit, and temperature/ heat alarm circuit, PV and battery sizing. Solar geometry is important when the solar radiation's absorption is needed to be maximize, while the concept and type of secondary battery has led to choose the suitable battery for the system, which is the sealed-lead acid. The study of concept of automatic BMS has shown the three important parameters of maintaining battery lifetime: voltage, current and temperature.

The concept later has been used in constructing the new automatic BMS, which is cost-friendly. This automatic BMS is used for a battery, meaning battery monitoring has been made specific in this system. With the calculation of PV and battery sizing, the number of battery calculated made it possible to install each battery with this new automatic battery monitoring system. With that installation, the battery is predicted to maintain its lifetime for at 5 years, which is a typical lifetime for battery under the temperature of $33^{o}C$. It is hoped that this project will give great contribution in helping to make solar as a major alternative in future. The objectives of this project finally achieved.

5.2 Recommendation

This project can be modified with new features such as computerized all the data of voltage, current and temperature. This implementation will make monitoring the data easier as user can just monitor the battery through computer. Also, using computer, the system can perform various activities such as comparing each values of battery for future reference. The computerized system is also more reliable compared to the circuitry system.

This system can also be modified to monitor various numbers of batteries in one time. Before this, the monitoring system is specific only to a battery at one time. However, by modifying the monitoring system for lots of batteries will make the whole system much more efficient.

This project is valuable in PV application. Thus, it can be developed further so that its usage can be fully enhanced.