SOLAR POWERED STREET LIGHTING

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LIST OF ABBREVIATIONS

SEE	School of Electric & Electronic
TNB	Tenaga Nasional Berhad
SSR	Solid State Relay
PV	Photovoltaic
CCT	Correlated Color Temperature
AC	Alternating Current
DC	Direct Current
MPPT	Maximum Power Point Tracker
AGM	Absorption Glass Matte
USB	Universal Serial Bus
VDC	Voltage Direct Current
VAC	Voltage Alternating Current
LED	Light Emitting Diode
HPS	High-Pressure Sodium

LIST OF SYMBOLS

α	Absorption coefficient
W	Watt
H	Luminous efficacy
Φ	Luminous flux
K	Kelvin
A	Ampere
V	Volt
lm	Lumen
lx	Lux
Ω	Ohm
m	Meter
Ө	Phase angle

ABSTRACT

Solar Powered Street Lights is a project that can help Universiti Sains Malaysia School of Electrical & Electronic (SEE) in electricity cost savings by implementing the use of existing solar PV system. Because the cost of electricity to the national grid Tenaga Nasional Berhad (TNB), which continues to increase, the system is able to maximize cost savings for SEE. Solar energy collected during the day will be converted into electricity to charge the battery. Electricity charged will be connected and used to power the lights around the SEE parking area at night. Taking into account all important aspects that help to optimize energy saving, this system is proven to reduce electricity costs. System data such as the power consumption by the load, battery charging rates, and other relevant data is measured. From the measured data, calculations and analysis were performed to determine the actual performance of the system. Proper wiring connections between solar PV systems and light poles grid around the SEE parking lot have been executed. Appropriate types of light bulbs have also been installed on light poles around the SEE parking lot. This type of light bulbs consumes electricity at a rate that is not too high and generate an appropriate level of visibility at night. As a result, the implementation of this system could save as much as RM 462.86 for the cost of monthly electricity bills incurred by the SEE.

ABSTRAK

Lampu Jalan Bertenaga Suria adalah sebuah projek yang dapat membantu Pusat Pengajian Elektrik & Elektronik (SEE) Universiti Sains Malaysia dalam penjimatan kos elektrik dengan melaksanakan penggunaan sistem PV solar sedia ada. Oleh kerana kos elektrik grid kebangsaan Tenaga Nasional Berhad (TNB) yang terus meningkat, sistem ini berupaya memaksimumkan penjimatan kos untuk SEE. Tenaga solar yang telah dikumpul pada siang hari akan ditukar kepada tenaga elektrik untuk mengecas bateri. Tenaga elektrik yang telah dicas akan bersambung dan digunakan untuk memberi kuasa kepada lampu kompaun di sekitar kawasan tempat letak kereta SEE pada waktu malam. Dengan mengambil kira semua aspek penting yang membantu untuk mengoptimumkan penjimatan tenaga elektrik, sistem ini terbukti dapat mengurangkan kos elektrik. Data sistem seperti penggunaan kuasa oleh beban, kadar pengacasan bateri dan data lain yang berkaitan diukur. Daripada data yang diukur, pengiraan dan analisis telah dilakukan untuk menentukan prestasi sebenar sistem. Sambungan pendawaian yang betul antara sistem PV solar dan grid tiang lampu sekitar kawasan tempat letak kereta SEE telah dilaksanakan. Jenis mentol lampu yang sesuai juga telah dipasang pada tiang-tiang lampu sekitar tempat letak kereta SEE. Jenis mentol lampu ini memakan kuasa elektrik dengan kadar yang tidak terlalu tinggi dan menghasilkan kadar penglihatan yang sesuai pada waktu malam. Hasilnya, pelaksanaan sistem ini dapat menjimatkan sebanyak RM 462.86 bagi kos bil elektrik bulanan yang ditanggung oleh SEE.

CHAPTER 1

INTRODUCTION

1.1 Overview

During this era, light is not limited in its use but also used for comfort, decor, and security in our daily lives. The high demand and the implementation of green technologies in most modern projects make solar energy is becoming more popular nowadays. School of Electrical & Electronic (SEE) of Universiti Sains Malaysia also rise to the challenge and try to use this technology to optimize electricity savings in the SEE parking lot at night.

This project implements this idea by using existing SEE solar PV harvester to get electricity from solar energy conversion. The electric current that has been produced charging and stored in batteries for the use by the compound light around SEE parking area at night. As the backup, Tenaga Nasional Berhad (TNB) power grid is also supplied to the system in case of battery power supply has been used up. Auto-switch is designed to control the two separate power sources using the combination of Arduino UNO and solid state relay (SSR).

This system able to maximize the power and cost savings in electricity bills because it uses renewable energy sources. The combination of these two sources of power from the rechargeable battery and TNB grid ensure continuous power supply to the lights around the SEE car park at night.

1.2 Problem Statement

SEE has spent quite a lot of money just to pay for monthly electricity bills. To reduce the burden a little bit, the challenge of implementing green technology into SEE is accepted. By implementing solar energy systems, power and cost savings can be maximized as this system using the source of renewable energy from the sun. The system is implemented to provide electricity to the SEE car park lighting system at night.

1.3 Objective

Based on the problem that stated above, following objectives are set to tackle the issue. The objectives of this project are:

- To analyze the performance data of the solar PV energy harvester that support the compound lights around SEE parking lot during the night.
- To connect the solar PV harvester system with the compound lights grid around SEE parking lot.

1.4 Project Scope

In this project, Solar PV harvester serves to support the SEE compound at night by using the power supply from the charged battery during the day. TNB grid acts as a backup power supply in case the battery is no longer able to supply power to the load. The switching of the two power sources is controlled by the auto-switch that has been designed. Data related to the project system performance are measured, recorded and analyzed.

1.5 Thesis Overview

Chapter 2 summarizes the research information from previous research that is related to the solar energy system and its application. It explains how the solar energy system that can be applied to optimizes energy saving in daily life. The concept improvement from the previous research of the solar energy system will be explained here.

Chapter 3 provides the discussion of methods being applied on this project. The flow chart, block diagram, design procedure of solar panel and measurement procedure will be explained in this chapter.

Chapter 4 focuses on the results and data analysis. This chapter will show the obtained data from measurement and calculation that has been conducted. Next, the obtained data and measurement that related to this project are being analyzed.

Chapter 5 concludes the project from the beginning stage until the stage of implementations. The limitations of the system and future works will be discussed and suggested here.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Research papers that related to this project from various researchers are reviewed and discussed in this chapter.

2.2 The Grid-Tied solar power supply

The grid-tied solar system is a system that is attached to the power grid. This is because there is the possibility of the solar panels are not able to generate enough power which is influenced by several environmental factors.

Most of the solar PV system was introduced as a backup power supply. If the national grid power supply is damaged, the power supply will be switched to solar PV as support. This is to ensure continuous power supply if trouble like this happens [1].

Besides, there is also a counter operation of this system by using solar PV as the main power supply and the national grid acting as a backup. By using this system, the use of solar PV power supply can be maximized and can reduce waste of electrical energy. In addition, by implementing this method, the system can reduce energy costs because it uses renewable energy sources rather than continually using the national grid power supply that charges the user.

2.3 Solar PV Panels

Solar PV panels are used in the conversion of light into electrical energy. Sufficient energy produced as the light beams to the PV panel for free electrons to be free from their atoms. Each solar cell consists of a built-in potential barrier that acts on free electrons to produce a voltage that can be used to drive an electric current through the circuit. When the relatively low energy light is absorbed by a solid, it produces heat that causes the electrons in solar cells to vibrate. Otherwise, the high energy light can change the properties of solar cells and make bonding atoms release electrons. Electrons and holes were released from their positions in solar cells and generate electron-hole pairs. Generating electrons and holes by light is the main process PV effect [2].

Each of PV cells containing a barrier with the opposite charge facing each other. Both barriers will send the electron more to one side and holes to the other side. During the separation process occurs, electrons and holes are likely to recombine. This leads to the losses of their electrical energy .This charge separation induces a voltage difference between the potential barriers. This will generate a current that can be used by an external circuit. Potential barrier in the solar cell separates the light generated charge carriers process is shown in Figure 2.1.

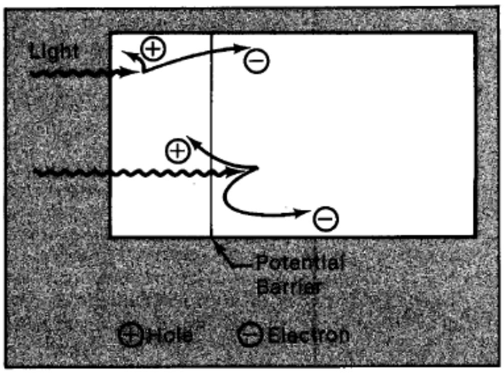

Figure 2.1: Potential Barrier in a solar cell separates light generated charge carrier, creating a voltage [2]

To make conversion sunlight into electricity more efficient, solar cells needs to harvest a significant fraction from solar radiation spectra. The absorption efficiency depends on the absorption coefficient (α) of the material [3].

Solar PV panel connection also plays an important role in improving the efficiency of electric current. Parallel wiring will produce the same output voltage while increasing the output electric current. Parallel connection is used when the positive from a variety of modules are connected together and negative for the same modules are also connected together.

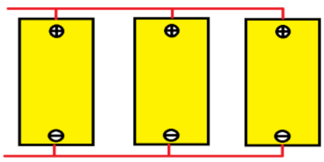

Figure 2.2: Example of parallel connection of PV module [4]

Series wiring makes the current output the same while increasing the current output of solar arrays. Series connection happens when positive one of the solar module and negative of another solar module connected together.

Serial wiring makes the same output electric current while increasing the output voltage of the solar arrays. The serial connection is used when the positive of a solar module and the negative of a different solar module is connected each other.

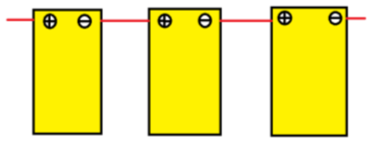

Figure 2.3: Example of series connection of PV module [4]

So, the combination of series connection and parallel connection are capable of producing higher output voltage and output electric current of the solar array.

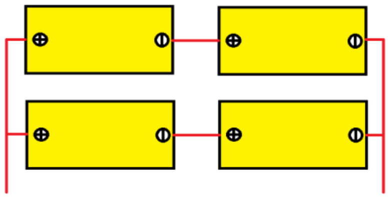

Figure 2.4: Example of series and parallel connection of PV module [4]

2.4 Battery Charging Phases

The internal resistance of a battery does increase as the battery discharging. As the battery becomes more charged, the voltage produced by it cells increases and opposes the charge current. This internal phenomenon of a battery is called as series opposing. The 3 common stages of battery charger use this phenomenon to determine which stage of charging to be applied from the battery charger. These 3 phases of charging a battery are known as bulk, absorption and float phase.

The initial phase if a charging battery is bulk charging. In this particular stage, the charger rapidly returns the battery to about 80%-90% state of charge by maintaining current at a high level. The high current is maintained constant against the rising internal resistance to charge current by increasing the voltage of the battery.

By considering the Ohm's Law, V=IR equation, to maintain a constant current with increasing resistance, the voltage must be raised as well. This charging phase continues until the output voltage by the charger reaches a specific level [5].

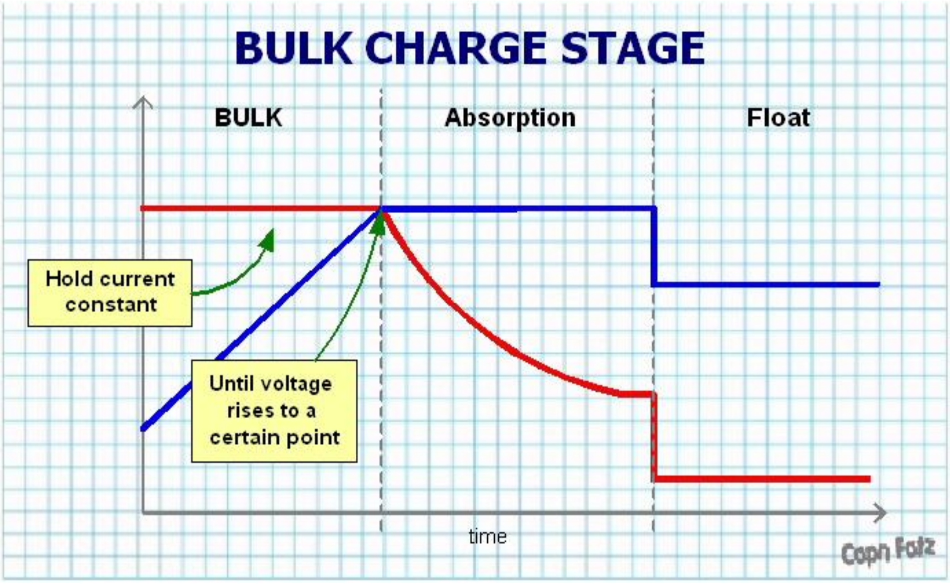

Figure 2.5: Bulk charging phase graph [5]

At the point where the output voltage reaches the specific level, the charging phase switches to absorption charging. Absorption charge current and voltage vary from the charger to charger. At this stage, the applied charge voltage is maintained at a constant level and charger starts to monitoring the supplied current. As the battery charging, the resistance to a charge current also increases and cause the current flow to decrease. By reconsidering the Ohm's Law, if the voltage is maintained and resistance increases, the current must be decreased. During the absorption phase, the charger monitors the falling current until it reaches a specified point which indicates the battery is almost fully charged and switch to the next charging stage.

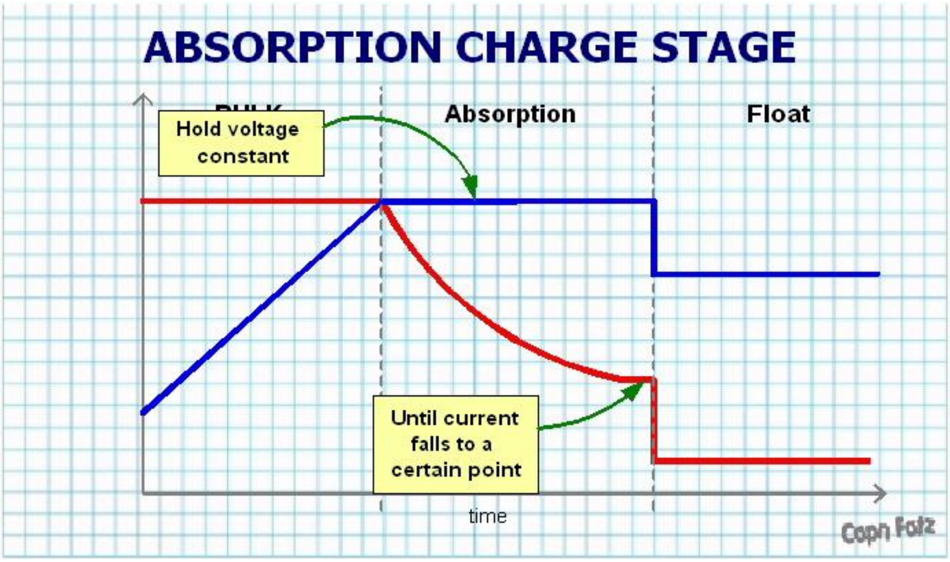

Figure 2.6: Absorption charging phase graph [5]

The final charging phase is called float charging. During this phase, the voltage is dropped to a lower level than the voltage that was applied in absorption phase. The purpose of this action is to bring the battery from almost-full state of charge to a full state of charge and maintain the battery at that state.

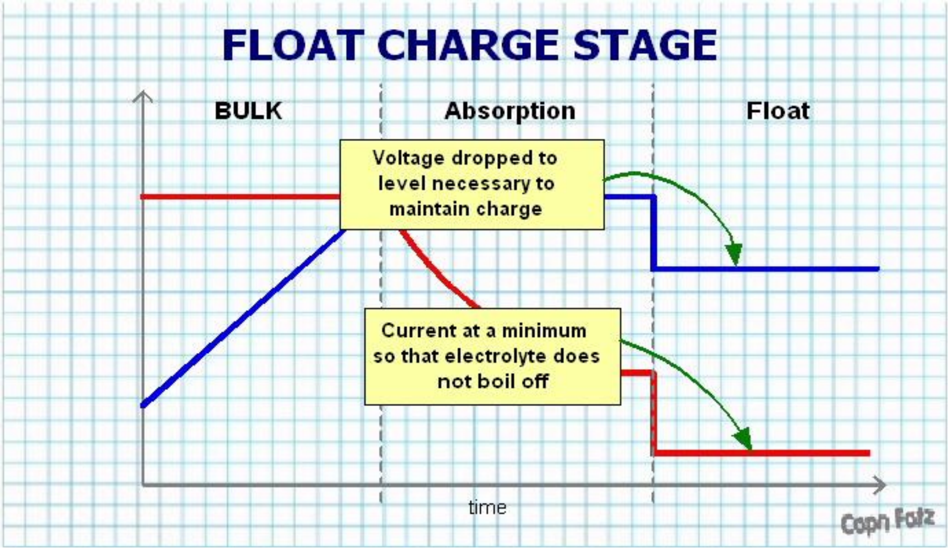

Figure 2.7: Float charging phase graph [5]

There are several ways to keep the battery at a full state of charge. Firstly, the voltage supply has to theoretically ideal to the type of battery being charged. This voltage level should be low enough to keep the electrolyte from boiling off and high enough to counteract self-discharge. Secondly, the state of charge and the applied voltage has to be monitored gradually. Some of smarter chargers uses temperature sensor and monitor the voltage level by using pulse width modulation technique

2.5 Light Visibility of a light source.

The ability of a light source to produce visible light within a certain area is called Luminous Efficacy (2.1). The SI unit for luminous efficacy is lm/W. It is measured by the ratio of luminous flux to the power of the light source [6].

$$\eta = \Phi / P \qquad (2.1)$$

where

η = luminous efficacy

Φ = luminous flux (lumens, lm)

P = power (W)

Luminous flux is the amount of light radiated from a light source per second. The unit for luminous flux is Lumens/lm. It is used to specify the total amount of light emitted by a light source. It is measured when the lamp is operated under standard condition. From the luminous flux, the value of Illuminance can be determined [7].

Illuminance is a measure of total luminous flux is spread over a certain area. The SI unit for illuminance is Lux/lx. The value of illuminance can be determined by using a sensor or the lux meter that available in the market. The closer the light source to a sensor, the greater the light's influence on illuminance that the sensor detects [8].

Color temperature is also one of the main factors in the visibility of a light source. It is an indicator to describe the light appearance provided by a light bulb. It is measured in degrees Kelvin (K) on a scale from 1,000 to 10,000. The color temperature of a light bulb is assigned using the basis of correlated color temperature (CCT) [9].

The Illuminance and color temperature are related each other that can affect the light visibility of a light source [8].

2.6 Switching Control Unit

Most of the solar PV system installed for the use at home or outside using the control timer for controlling the operation of the system. The timer control is essentially predetermined time to turn on or turn off the system automatically. Normally, the system has been timed to turn on the system for 12 hours at night and turn off the system for 12 hours during the day.

Some of the solar PV system uses a better approach to controlling the operation of the system by using a dark sensor. The dark sensor is used to detect the intensity of ambient light. Usually, it is installed between the power source and the load that allows current to flow to the load and turn on the system. The dark sensor is switched on if it detects the low light intensity or dark environments. If the sensor detects high light intensity or bright environments, it will be turned off [10].

2.7 Chapter Summary

Based on a literature review has been conducted, the implementation of solar PV systems can definitely reduce energy costs and maximize energy savings. Further steps to maximize the cost savings can be done by designing a system that fully uses power from solar PV harvester. The National grid will act as a backup power supply and support system if the solar PV harvester may not produce enough power to supply the load.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the hardware, software, and method applied in this project. All details on how the project has been conducted are discussed in this chapter.

3.2 Project Implementation Flow

A flow chart of this project is shown in Figure 3.1.

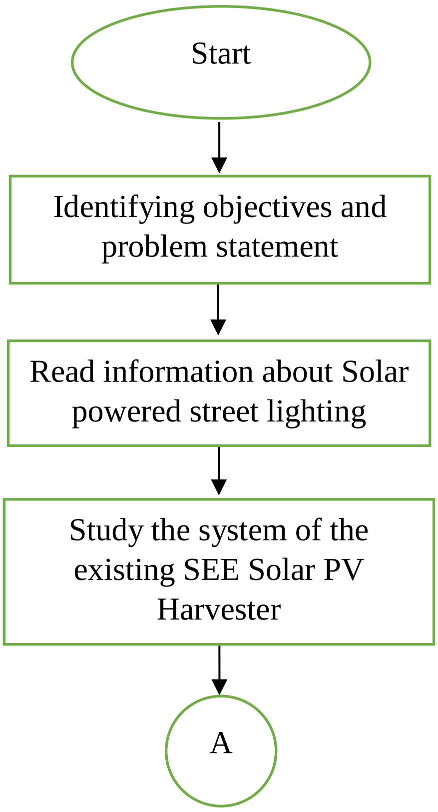

Figure 3.1 Project Flow Chart (continues…)

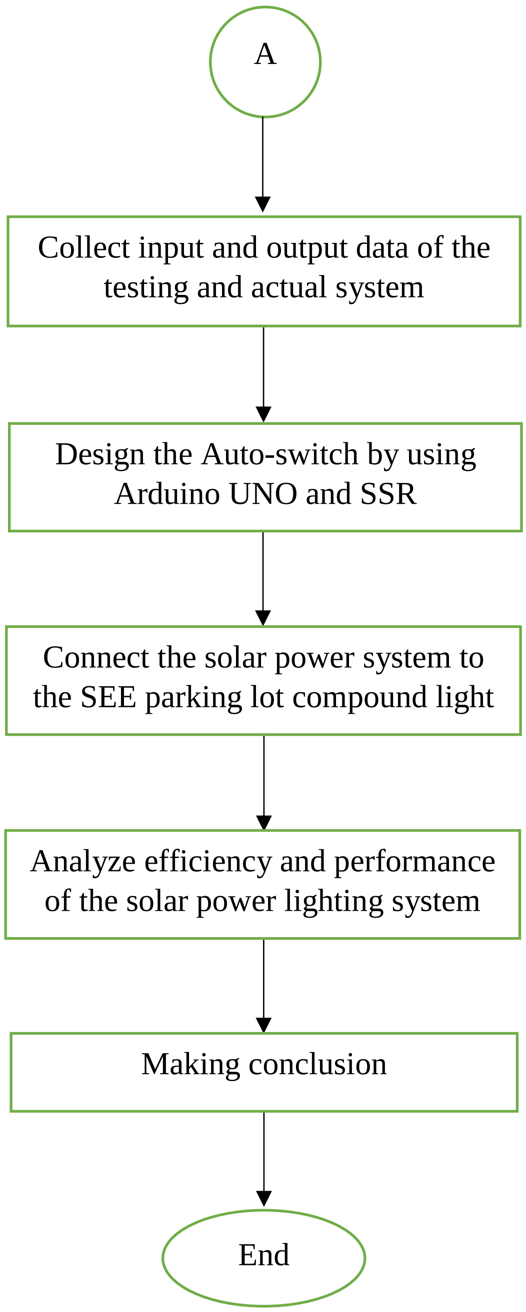

Figure 3.1: Project Flow Chart

3.3 Project Requirement

3.3.1 SEE Solar PV Harvester

Figure 3.2 : SEE Solar PV Harvester

The existing SEE Solar PV Harvester as shown in Figure 3.2, which is close to the SEE car park able to generate electricity by converting solar energy harvested from the sun. The converted electrical energy is stored in the battery which has been installed in the form of DC and inverted into AC for daily use. The system consists of numbers of equipment needed to make the system work properly.

a. Victron Energy BlueSolar Polycrystalline Panels

There is a total of 6 units of 300W Victron Energy BlueSolar Polycrystalline panels are used in this project as photovoltaic systems. 3 units of the total solar panels are connected in series and similarly for the remaining panels. Both series connections are combined in parallel as shown in Figure 3.3. Through this method, the output voltage and output current can be increased. This is because the connection of solar panels in series is able to increase the output voltage and the connection of the solar panels in parallel can also increase the output current [7].

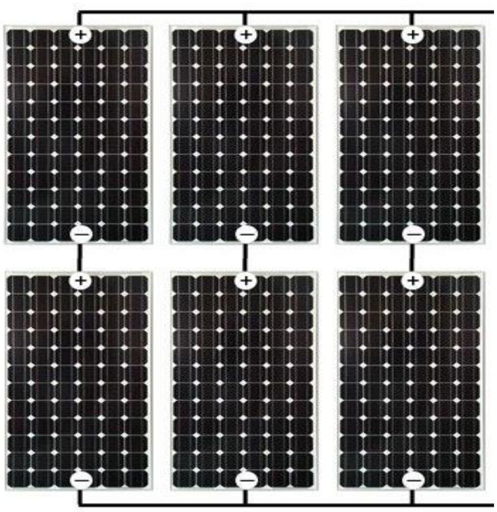

Figure 3.3: Series-Parallel Solar PV panel

b. Victron Energy EasySolar 48/3000/35-50

The EasySolar combines two MPPT solar charge controller and an inverter/charger in one enclosure as in Figure 3.4.

Figure 3.4: Victron Energy EasySolar 48/3000/35-50 [9]

The two solar charge controllers which are 2x Blue Solar MPPT 150-35 can be connected with six strings of PV panels to six sets of MC4 (PV-ST 01) PV connectors. The inverter/charger which is MultiPlus Compact 48/3000/35-50 and the MPPT charge controllers share the DC battery connection. Hence, the batteries can be charged with solar power and/or with AC power from the utility grid in available ACin port. The system basically uses AC power from the grid TNB main power supply to the load and the battery as a backup power in case of grid TNB suffered damage.

c. **Victron Energy AGM 'Deep Cycle' Battery**

Absorbent Glass Mat (AGM) deep cycle batteries as in Figure 3.5 have excellent high current performance and are therefore recommended for high current application. There are 4 of Deep Cycle AGM (130Ah, 12V) batteries are connected in series used to store the charge produced from solar PV panels.

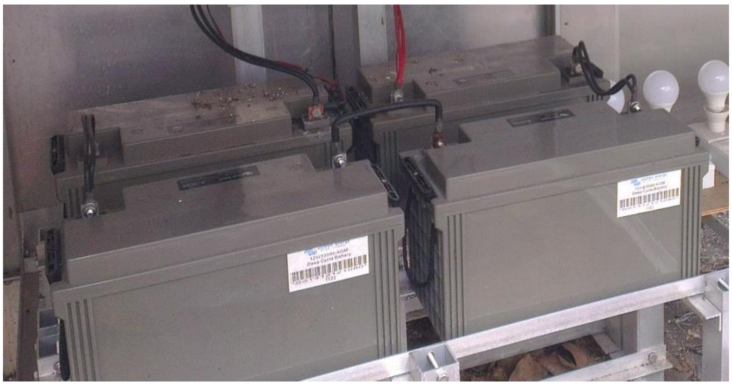

Figure 3.5: 130Ah, 12V Victron Energy AGM 'Deep cycle' battery

d. **Victron Energy BMV-700 series: Precision Battery Monitoring**

Victron Energy BMV-700 series as in Figure 3.6 is used to monitor the batteries performance. The remaining battery capacity depends on the ampere-hours consumed, discharge current, temperature and the age of the battery. Complex software algorithms are needed to take all these variables into account. Next, to the basic display options, such as voltage, current, and ampere-hours consumed, the BMV-700 series also displays state of charge, time to go, and power consumption in Watts.

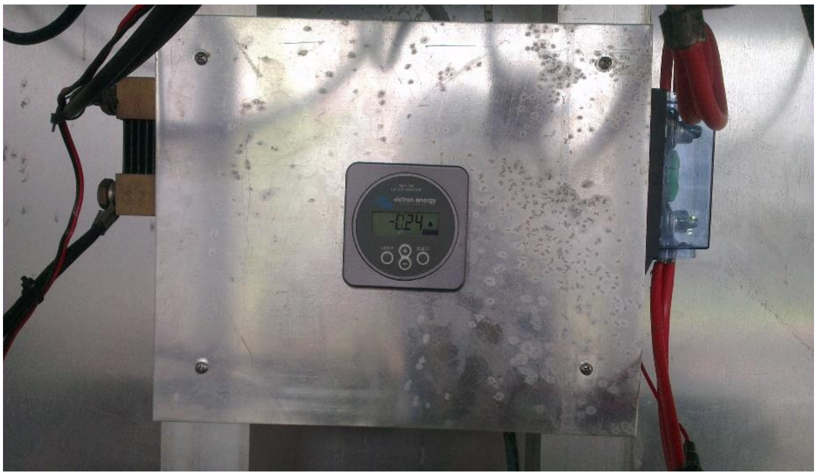

Figure 3.6: Victron Energy BMV-700 series : Precision Battery Monitoring

3.3.2 Auto-Switch System

Auto-switch system is designed to reverse the operation of the SEE Solar PV Harvester which using the TNB grid power supply as its priority and the batteries as backup power supply. By this method, power saving and cost saving can be maximized. This auto-switch consist of several components that important to make this system functioning well.

a. Crydom Solid State Relay (SSR)

This type of SSR has to get input in the range of 3-32VDC to control the output voltage in the range of 24-280VAC. With Arduino UNO is capable of supplying 5VDC for SSR control input and the output voltage able to support the 240VAC from TNB, this SSR is suitable to be used in the system. The 240VAC supply output voltage will be blocked except the SSR receiving a 5VDC input voltage.

Figure 3.7: Crydom Solid State Relay (SSR)

b. Arduino UNO

Arduino UNO is used to control the auto-switch system. It is programmed to sense the voltage of the batteries. From the voltage reading, Arduino UNO will control the operation of the SSR which act as the 240VAC TNB grid control switch. To activate the Arduino UNO, a USB phone charger is used to give 5VDC power supply from the 240VAC TNB grid.

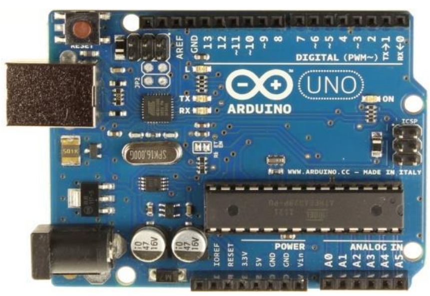

Figure 3.8: Arduino UNO

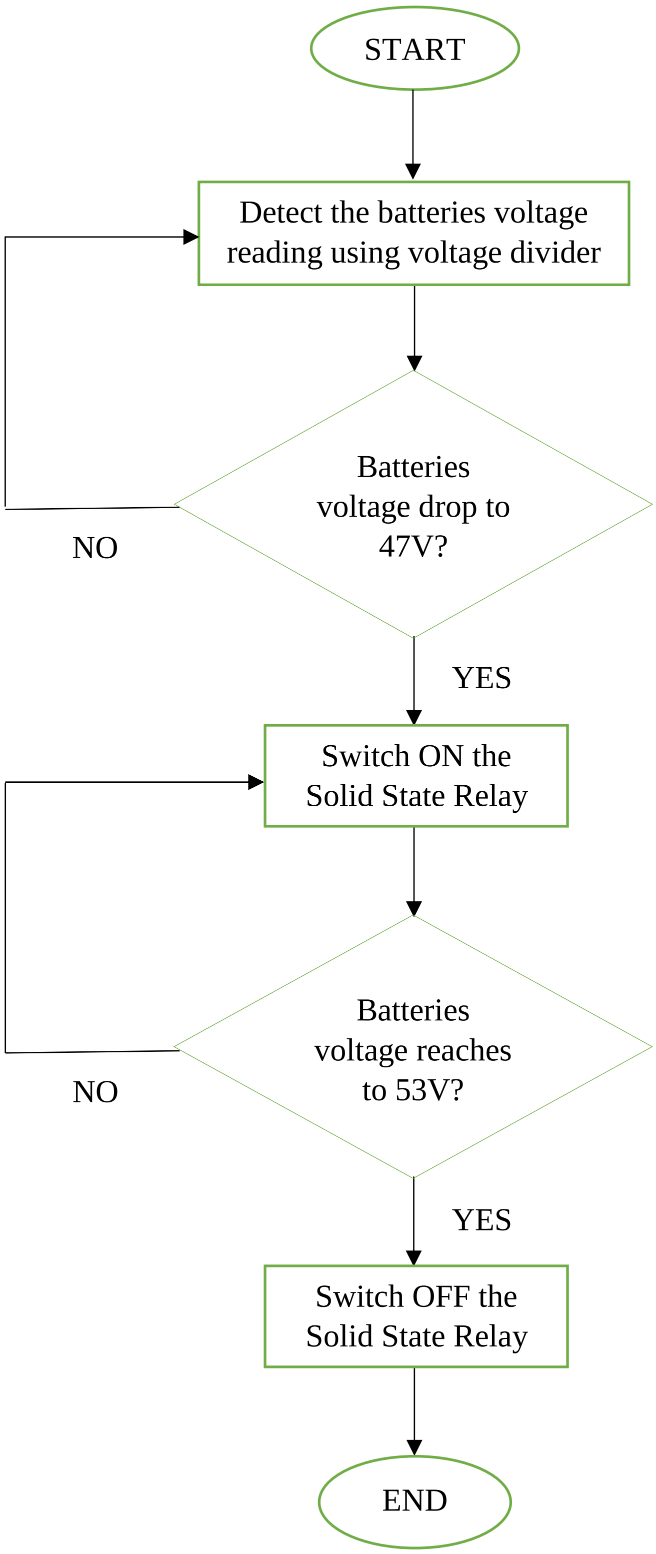

Figure 3.9: Arduino UNO software flow chart

c. Voltage Divider as Voltage Sensor

The concept of the voltage divider is used in this system to act as the voltage sensor of the batteries. It will detect the voltage of the batteries and send the data to the Arduino UNO that has been programmed to interpret the data and process the voltage reading of the batteries.

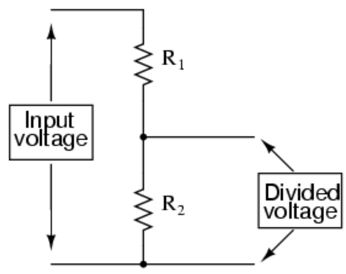

Figure 3.10 : Concept of Voltage Divider

3.3.3 Different types of light bulbs

For the testing, different types of light bulb are used to determine the performance of the solar PV system for each light bulbs. As each type of light bulbs have different specifications, so it is important to determine the amount of power consumption which can affect the time duration of the battery power supply. Each type of light bulbs also produces different lux reading. As the lux readings increases, visibility generated by the light source also increases. A total of 9 light bulbs of various types is required to be tested which also represents the total number of light poles that surround the parking area SEE.

Figure 3.11: Light Bulb Testings Setup

3.3.4 Dark Sensor

The dark sensor is used as load switch. It turns the load on during the night and off during the day. The dark sensor is connected between the ACin port of the Victron Energy Easy Solar and the load. It is installed outside the solar PV harvester house to detect the light.

The dark sensor is used as a switch to the load. It will turn the load on at night and turn off the load during the day. The dark sensor is connected between AC input port of Victron Energy Easy Solar and the load. It is installed outside the solar PV harvester house for detecting the level of lighting.

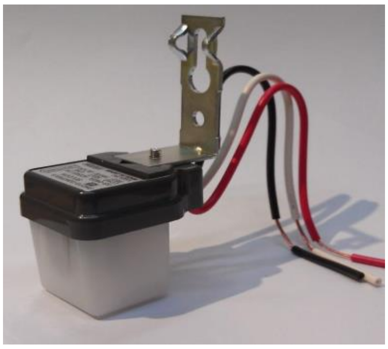

Figure 3.12 : Selcon 240VAC 6A Dark Sensor

3.4 Project Design

3.4.1 Overall Project Setup

There are six Victron Energy BlueSolar Polycrystalline Panels connected in series-parallel are used to harvest the solar energy during the day. The charging and inverting process will be controlled by the Victron Energy EasySolar 48/3000/35-50. The electricity that has been charged will be stored in the batteries. For voltage storing part, there are 4 of Victron Energy AGM ‘Deep Cycle’ batteries connected in series are used. Victron Energy BMV-700 series is used to monitor and indicates the battery data. The stored electricity is then being converted into AC by EasySolar before being supplied to the LED bulbs. Arduino UNO and SSR are used to control the power supply from the TNB grid. TNB power supply will be connected to AC input port that available on Victron Energy Easy Solar to charge the batteries and give supply to the load at the same time if the batteries are not able to supply power to the loads at night.