PHOTOVOLTAIC AND LED COMBINATION FOR RECYCLE WASTE OF LIGHT ENERGY

Mohd Fadhillullah Bin Abdullah
Faculty of Electrical Engineering
Universiti Teknologi MARA Malaysia
40450 Shah Alam, Selangor, Malaysia
email address: fahd_hdill@yahoo.com

Abstract --**In this paper, report consist the results of the experiment that conducted to design photovoltaic and LED combination system. This combination system looks like a small standalone photovoltaic systems with LED as load. The system uses battery that has two functions as main source to light LED and as storage for photovoltaic system. The energy sources drain by photovoltaic effect on two conditions. First condition the energy gain from sun during daylight that capture by photovoltaic module. Second condition the energy gain by extract waste of light energy to electrical energy from LED light source. The designation involve of choosing the photovoltaic module type, photovoltaic maximum power, photovoltaic system parameter, battery capacity, charging and discharging rate of battery and controller and LED parameter.**

Keywords- photovoltaic; LED; combination system

I. INTRODUCTION

The most interested to discover is the combination effects of the photovoltaic and light source which means electrical and sun light sources. This is important when we want to make the comparation between differential types of light sources.

The second part that concern in this research is charging and discharging effect to the battery and PV module. The limit overcharge and over discharge must be considered to protect the battery from damage or total lost.

Comparation between two conditions of light source must clearly before design the system. There are several components in radiation of sunlight's emission that come to earth atmosphere. The differentiation between those components comes in term of electromagnetic frequency.

It is important to know what component of radiation that extracts by different type of PV module. The different type of radiation gives a differential on output parameter.

The experiment in this research based on two types of PV module and differential between different light sources. Those two module type are monocrystalline and polycrystalline.

II. SYSTEM DESCRIPTION

In this combination system consisted of a photovoltaic array, a battery, a charge controller and a LED as a load. A simplified schematic of a typical system is shown in Figure 4.01.

A. Light Source

1) Sun

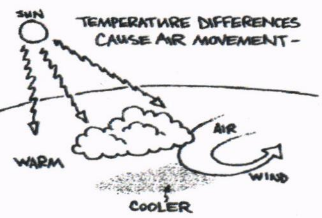

Figure 1.01. sun as a main light source[1]

Basically, the Earth is a huge solar energy collector because it collects the energy from the sun. Those consequent affect of forming the natural energy such as wind energy. [1]

2) Load

In this research, there are two main experiments was conducted based on two main load and two different type of PV module.

a) LED

LEDs have proven to be extremely effective due to their long lifespan and increased efficiency. [2]

b) Incandescent Bulb

Some advantages of incandescent bulbs are: they are relatively easy to produce, they are cheap to produce, of all artificial light sources, they most closely resemble natural sunlight, and they contain no toxic materials.

The major disadvantages of incandescent bulbs are directly related to their inefficiency. These disadvantages are: 90% of the energy they consume is lost to heat, and they contain filaments which burn out, reducing their life span. [3]

3) PV module

Solar cells, also called photovoltaic (PV) cells by scientists, convert sunlight directly into electricity

a) Monocystalline

Highest efficiency, approx. 17%. The most expensive. Lower temperature coefficient compare to Polycrystalline (-0.45%/^{0}C).

b) Polycrystalline

Cheaper and lower efficiency (approx. 15%) than monocrystalline. Higher temperature coefficient than monocrystalline (-0.5%/^{0}C). [4]

4) Battery

a) Battery capacity

The number of amp-hours that can be withdrawn from a battery at a specified discharge rate, before the battery drops to a specified low voltage after the battery has been charged by a power supply that provides both bulk and finishing charge cycles.

b) Battery state-of-charge

Battery state-of-charge is the number of amphours that can be withdrawn from a battery at the time of a particular test when the battery is discharged at a specified rate to a specified low voltage. [5]

III. TEST PROCEDURE

To develop the best system using effective light source, must know the different effect and factor of each light source. Then compare the differential and select the good light source that have more advantages. In this project there are two selected light source normally used. It is LED and Incandescent lamp.

Electrical Characteristics

	SX 10
Maximum Power (P_{max})[2]	10W
Voltage at P_{max} (V_{mp})	16.8V
Current at P_{max} (I_{mp})	0.59A
Warranted minimum P_{max}	9W
Short-circuit current (I_{sc})	0.65A
Open-circuit voltage (V_{oc})	21.0V
Temperature coefficient of I_{sc}	(0.065±0.015)%/°C
Temperature coefficient of V_{oc}	-(80±10)mV/°C
Temperature coefficient of power	-(0.5±0.05)%/°C
NOCT[3]	47±2°C

Figure 2.01. Specification of polycrystalline PV module.[10]

Electrical Characteristics	
Open - Circuit Voltage (Voc)	21.7V
Optimum Operating Voltage (Vmp)	17.6V
Short - Circuit Current (Isc)	1.26A
Optimum Operating Current (Imp)	1.14A
Maximum Power at STC (Pmax)	20Wp
Operating Temperature	-40°C to +85°C
Maximum System Voltage	715V DC
Maximum Series Fuse Rating	N/A
Power Tolerance	±5 %
STC: Irradiance 1000W/m2, Module temperature 25°C, AM=1.5	

Temperature Coefficients	
Nominal Operating Cell Temperature (NOCT)	45°C±2°C
Temperature Coefficiency of Pmax	-0.48 %/°K
Temperature Coefficiency of Voc	-(78±10) mV/K
Temperature Coefficiency of Isc	0.055 %/K

Figure 2.02. Specification of Monocrystalline PV module. [9]

A. Experiment 1

Characteristics and factors of energy transfer by using Led light

1) Experiment Outcome

Upon completion of this experiment, the result should have done the followings:

EO1-Effective gap's length between light and PV with change of the PV current and voltage

EO2-Effect of different type LED

TABLE 2.01. EQUIPMENT FOR EXPERIMENT A

No	Equipment	Quantity (unit)
1	Pyranometer	1
2	Photovoltaic module	2 different type
3	digital multimeter	2
4	Tape meter	1
5	LED	1

2) Procedure

a) Lay down the PV module at the bottom of light source. Set one multimeter for measure PV current and other one for measure voltage. Put reference resistor with better resistance value to measure voltage. Switch ON the light source. Make sure the light and PV module in symmetry position. For first experiment, use first selected PV module of small size.

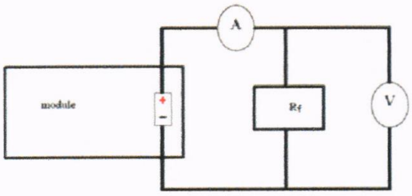

Figure 2.03. Measuring currents and voltages of a PV module.

b) Take Pyranometer on PV module. Record irradiation value. Remove Pyranometer and record current and voltage multimeter value. Repeat experiment by using LED with different power. Result all measurement in table 2.02 below.

No.	LED power (watt)	Current (A)	Voltage (V)	Irradiation (watt/m2)

c) Repeat experiment but change PV size to larger size. Result all measurement in table.

d) Repeat experiment but change PV module type to second selected PV module and small size. Result all measurement in table.

e) Repeat experiment of second selected PV module but change PV size to larger size. Result all measurement in table.

B. Experiment 2

Photovoltaic's parameters effect by different light source.

1) Experiment Outcome

Upon completion of this experiment, the result should have done the followings:

EO1- Analyse the photovoltaic's parameters effect by different light source emission.

EO2-Analyze the different light irradiation by different light source.

TABLE 2.03. EQUIPMENT FOR EXPERIMENT B

No.	Equipment	Quantity (unit)
1	Pyranometer	1
2	Photovoltaic module	2
3	digital multimeter	2
5	Incandescent lamp	1 (120watt)

2) Procedure

a) Take same part as procedure a, b and c in experiment 1 above. First experiment using LED as light source.

b) Repeat experiment by changing LED with different light source. Result all measurement in table 2.04 below.

No.	Light source type	Current (A)	Voltage (V)	Irradiation (watt/m2)

IV. RESULT

A. Result A1, LED light-Photovoltaic type used is polycrystalline type

TABLE 3.01. RESULT FOR 1.6 METER HEIGHT

LED Power	15 Watt
Height Between PV & LED	1.60 meter
Irradiance	7 Watt/m^2
Voltage	13.5 V
Current	5.55 mA

TABLE 3.02. RESULT FOR 1.4 METER HEIGHT

LED Power	15 Watt
Height Between PV & LED	1.40 meter
Irradiance	16 Watt/ m^2
Voltage	13.5 V
Current	5.82 mA

TABLE 3.03. RESULT FOR 0.6 METER HEIGHT

LED Power	15 Watt
Height Between PV & LED	0.60 meter
Irradiance	37 Watt/ m^2
Voltage	15.5 V
Current	5.55 mA

B. Result A2, LED light-Photovoltaic type used is monocrystalline type

TABLE 3.04. RESULT FOR 1.6 METER HEIGHT

LED Power	15 Watt
Height Between PV & LED	1.60 meter
Irradiance	7 Watt/m^2
Voltage	12.5 V
Current	8.05 mA

TABLE 3.05. RESULT FOR 1.4 METER HEIGHT

LED Power	15 Watt
Height Between PV & LED	1.40 meter
Irradiance	16 Watt/ m^2
Voltage	13.22 V
Current	9.07 mA

TABLE 3.06. RESULT FOR 0.6 METER HEIGHT

LED Power	15 Watt
Height Between PV & LED	0.60 meter
Irradiance	37 Watt/ m^2
Voltage	13.68 V
Current	9.88mA

C. Result B1, Incandescent light-Photovoltaic type used is polycrystalline type

TABLE 3.07. RESULT FOR 1.6 METER HEIGHT

Bulb Power	120 Watt
Height Between PV & Bulb	1.60 meter
Irradiance	3 Watt/m^2
Voltage	10.97 V
Current	2.61 mA

TABLE 3.08. RESULT FOR 1.4 METER HEIGHT

Bulb Power	120 Watt
Height Between PV & Bulb	1.40 meter
Irradiance	5 Watt/ m^2
Voltage	11.37 V
Current	2.89 mA

TABLE 3.09. RESULT FOR 0.6 METER HEIGHT

Bulb Power	120 Watt
Height Between PV & Bulb	0.60 meter
Irradiance	10 Watt/ m^2
Voltage	13.31 V
Current	5.47 mA

D. Result B2, Incandescent light-Photovoltaic type used is monocrystalline type

TABLE 3.10. RESULT FOR 1.6 METER HEIGHT

Bulb Power	120 Watt
Height Between PV & Bulb	1.60 meter
Irradiance	3 Watt/m^2
Voltage	10.52 V
Current	4.85 mA

TABLE 3.11. RESULT FOR 1.4 METER HEIGHT

Bulb Power	120 Watt
Height Between PV & Bulb	1.40 meter
Irradiance	5 Watt/ m^2
Voltage	10.96 V
Current	5.49 mA

TABLE 3.12. RESULT FOR 0.6 METER HEIGHT

Bulb Power	120 Watt
Height Between PV & Bulb	0.60 meter
Irradiance	10 Watt/ m^2
Voltage	13.30 V
Current	9.92 mA

Although the power of incandescent lamps is high but power produces from photovoltaic effect too small. It is because incandescent lamps produce large amounts of heat as a by-product. Approximately 90% of the energy that is consumed in an incandescent lamp is release in the form of heat while only 10% is converted to visible light. [6]

V. HARDWARE DESCRIPTION

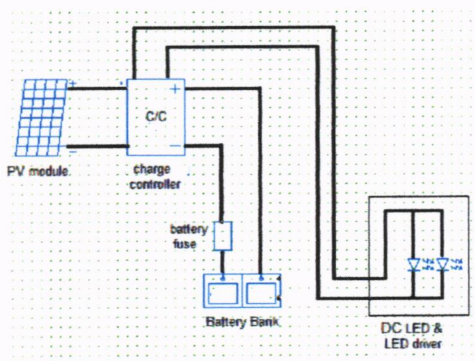

Figure 4.01. Hardware schematic diagram

The hardware main operation is divided in two modes. One of them is during daylight and another situation during day night.

A. During daylight

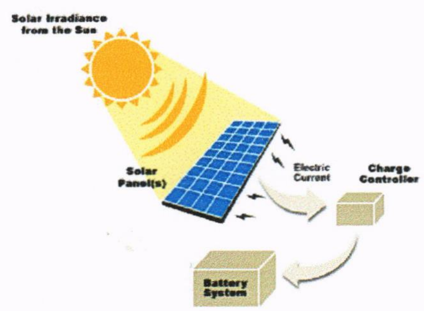

Figure 4.02. Hardware operation flow during daylight

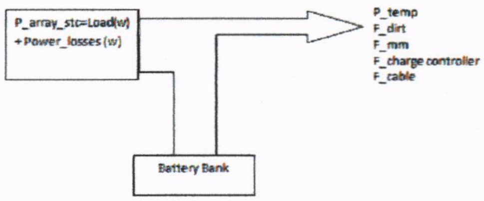

Figure 4.03. Hardware power flow during daylight

During daylight PV module receive light energy from sun. The light energy converted to electrical parameter by photovoltaic effect.

Since the no load at this state, this system specially designs for how much it can collect energy during daylight to store in battery bank.

The charging process is control by charge controller. During charging process, voltage parameter must not exceed overcharge limit or it can damage the battery bank. When the limit archive, charge controller detect overcharge limit and immediately cut off the supply from PV module.

B. During day night

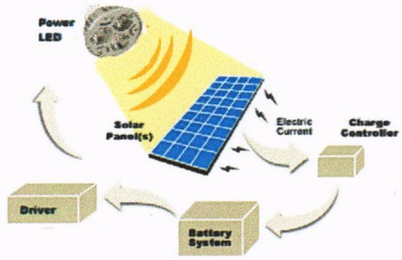

Figure 4.04. Hardware operation flow during day night

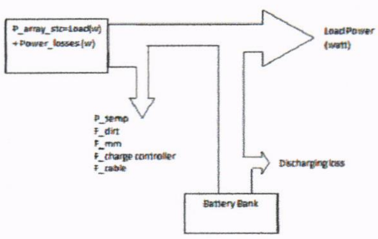

Figure 4.05. Hardware power flow during day night

In practice, at initial condition the battery shall be fully charged. So, at the first start LED can use directly energy from battery bank.

The light from LED is emission to surrounding to meet the user need. Normally, that light energy goes too dissipated to surrounding and loss to atmosphere. But what this system does is to recollect that waste of light energy to recycle to electrical energy.

The power cycle rotate from PV module convert that waste of light energy to electrical parameter. After that, the charging process control by charge controller to store energy in battery bank. Otherwise, that energy can directly used by LED as a load.

That means the energy supply to the load no longer fully supported from battery bank. It also contributed by recycle energy from waste of light energy. So, the battery storage or battery bank storage can maintain in longer time to discharge because those two energy combination.

VI. HARDWARE DESIGNATION

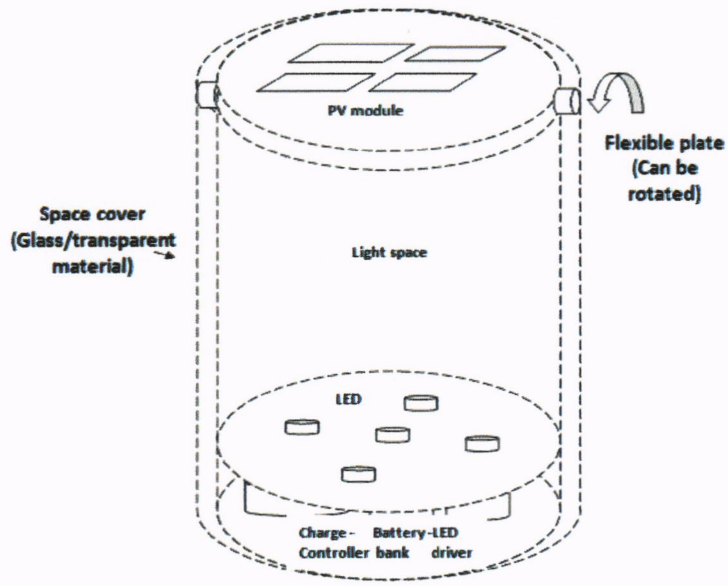

Figure 5.01. Hardware specification

For Load = LED 15watt
Assume [7]
Normally on Malaysia Peak Sun Hour (PSH) is between 4.5 until 5.0 hour.
PSH=5
Charging efficiency = 85%
Discharging efficiency = 90%
System voltage = 12V
Dirt factor = 0.99
Efficiency of charge controller= 95%
DODmax =80%
Average daily maximum temperature = 33°C
Cable loss from PV to battery =1%
Cable loss from battery to load=1%

A. Battery

The battery capacity ampere hours (Ah) required is determined by using the formula of standalone system.

$$Ah = \frac{E_{load_{daily}} \text{ x Autonomy}}{\eta_{cable_{pv_{batt}}} \; x \; \eta_{discharging} \; x \; DoD_{max} \; x \; Sys_{volt} \; x \; \eta_{inv}} \quad (1)$$

$\eta_{cable} = 0.99$ (PV to battery)

$$Ah = \frac{105\text{watt x 1day}}{0.99 \; x \; 0.9 \; x \; 0.8 \; x \; 12v}$$

Since the load is DC LED there is no need of inverter in this system. Then efficiency of inverter is equal to 1.0.

Ah battery capacity required is, Ah = 12.27 Ah

This system design for used in 1 day and in the day night only. So, daily discharging time assume to be 7 hours. The estimation of LED to operate from 7.00pm to 12.00pm and plus minus 2 hours for extra time.

It is must be design as small as possible because for outdoor usage.Then, choose small battery with 7 hours rating of discharge. The battery capacity must be larger than 12.4 Ah. The range of battery capacity that should choose that available in the market is between 13 to 15Ah. [8]

B. PV size

The size of PV array required can be determined by:

$$Power_{PV} = \frac{Eload_{daily}}{PSH \; x \; f_{mm} \; x \; f_{temp} \; x \; f_{dirt} \; x \; \eta_{cable} \; x \; \eta_{charge_{controller}} \; x \; \eta_{charging} \; x \; \eta_{discharging} \; x \; \eta_{inv}} \quad (2)$$

$f_{dirt} = 0.99$

Since this system is portable, the dirty can easily cleaned.

$\eta_{cable} = 0.98$

For this small system, the losses from cable should be not effect too much on the system.

$\eta_{charge_{controller}} = 0.95$

1) For polycrystalline PV_type

$$\text{Mismatch}, f_{mm} = \frac{V_{min}}{V_{max}} = \frac{9watt}{10watt} = 0.9 \quad (3)$$

$$\text{Temperature}, f_{temp} = 1 + \left[\frac{\gamma_{voc}}{100}\left(T_{cell_{effective}} - T_{stc}\right)\right] \quad (4)$$

$$f_{temp} = 1 + [\frac{-0.5}{100}(33 + 25 - 25)]$$

$$f_{temp} = 0.8350$$

$$Power\_PV = \frac{105wh}{5 \; x \; 0.9 \; x \; 0.8350 \; x \; 0.99 \; x \; 0.98 \; x \; 0.95x \; 0.85 \; x \; 0.9}$$

$$Power\_PV = 39.63wp$$

Number of PV module =39.31/10 = 3.9632 roundup to 4 modules. For 12v system voltage, one string only needs 1 module. So, four modules connected in parallel.

a) The power generate from LED

TABLE 5.01. RESULT FOR 1.6 METER HEIGHT

Voltage	13.5 V
Current	5.55 mA
Number of PV_module	4
Total current	22.2 mA
Total power	0.2997 watt

TABLE 5.02. RESULT FOR 1.4 METER HEIGHT

Voltage	13.5 V
Current	5.82 mA
Number of PV_module	4
Total power	23.28 mA
Total power	0.3143 watt

TABLE 5.03. RESULT FOR 0.6 METER HEIGHT

Voltage	15.5 V
Current	5.55 mA
Number of PV_module	4
Total current	22.2 mA
Total power	0.3441 watt

2) For monocrystalline PV_type

Mismatch, f_{mm} = total efficiency of 10% which delivers the maximum power output [9] = 0.9

$$\text{Temperature}, f_{temp} = 1 + \left[\frac{\gamma_{voc}}{100}\left(T_{cell_{effective}} - T_{stc}\right)\right] \quad (5)$$

$$f_{temp} = 1 + [\frac{-0.48}{100}(33 + 25 - 25)]$$

$$f_{temp} = 0.8416$$

$$\text{Power\_PV} = \frac{105wh}{\frac{5\,x\,0.9\,x\,0.8416\,x\,0.99\,x\,0.98\,x\,0.95x}{0.85\,x\,0.9}}$$

$$\text{Power\_PV} = 39.32wp$$

Number of PV module =39.32/20 = 1.9661 roundup to 2 modules. For 12v system voltage, one string only needs 1 module. So, two modules connected in parallel.

a) The power generate from LED

TABLE 5.04. RESULT FOR 1.6 METER HEIGHT

Voltage	12.5 V
Current	8.05 mA
Number of PV_module	2
Total current	16.1 mA
Total power	0.2013 watt

TABLE 5.05. RESULT FOR 1.4 METER HEIGHT

Voltage	13.22 V
Current	9.07 mA
Number of PV_module	2
Total current	18.14 mA
Total power	0.2398 watt

TABLE 5.06. RESULT FOR 0.6 METER HEIGHT

Voltage	13.68 V
Current	9.88mA
Number of PV_module	2
Total current	19.76 mA
Total power	0.2703 watt

This hardware designed for outdoor activities normally on day night such as campaign, night fishing, for jungle area, at island area and etc.

C. Daylight

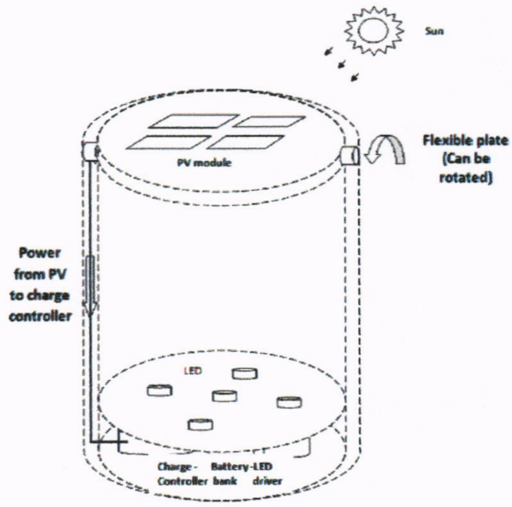

Figure 5.02. Hardware specification during daylight

On daylight PV module absorb irradiation of sunlight. The components in sunlight convert to electrical parameter. Electrical energy is store in battery bank.

D. Day night

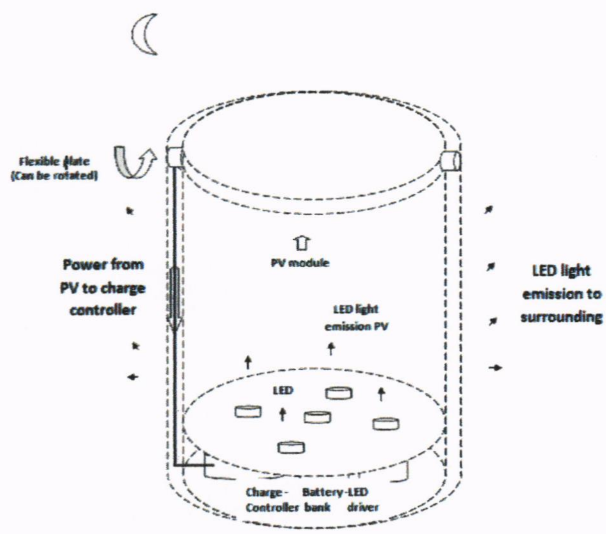

Figure 5.03. Hardware specification during day night

During day night, PV plate is flit to opposite side with LED. In this condition PV module can absorb light from LED and the convert to electrical energy.

VII. CONCLUSION

This project designation mainly based on the energy recycling to decreasing energy wastage. In practice, the electrical system is normally that energy enters a system equal to outgoing energy. If those outgoing energy can recycle and generate energy same as input energy, it can used to the system. That means this is some of improvement of efficiency of the system.

The efficiency improvement normally effect to cost and size of designation. For example battery sizing, since energy also can generated in day night by recycle waste of light energy from LED, the battery energy can used for long duration in the night time. The PV module also works effectively because it used for daylight and for day night.

On the experiment that conducted, there are several comparations between two electrical light sources incandescent bulb and LED. For designation, this system uses LED as electrical light source and as a load. The light generate from LED is purely light energy compare to incandescent light that a mostly contain of heat energy.

When sizing battery, what the most important is to consider the autonomy for load to maintain get continuous power.

For hardware designation, it's designed as can handle two condition of system mode operation during daylight and day night. It is also easy to control when condition change. So, the cost can reduce by compacting design.

IX. RECOMMENDATION

This system has design in calculation and experimentation only. For future recommendation, hardware must completely design in real form. So, the disadvantages are easy to reveal and to get some improvement.

There are different electromagnetic component from sunlight emission. Let do more research in the future about those component effect different type of PV module. It is because the powers that were collected depend on component in sunlight that was extract by PV module. There are not all components from sunlight turn to electrical energy. Some of them turn to heat energy. After complete these research, we may be able to construct new PV module that can extract all or more component from sunlight turn to electrical energy.

The experiment that was conducted just focus on two electrical light sources and two type of PV module. The two light sources are incandescent bulb and LED. While two different PV modules used are monocrystalline and polycrystalline. In the future the comparison should between more other light source and other different type of PV module.

This system functional only on single direction light beam from bottom to top or top to bottom. Some of adjustments in the future to make the light more shining maybe take two or more parallel light beam together or different direction. To get which is the best condition to take, another experiment that used two or more parallel beam must be conducted.

In this designation we do not more interested with the glass cover between bottom and top. To get better refractive of light that be transmitted to outside, the glass must be properly design. Or can put some type of gases in the space of the glass cover.

This hardware design for used for travel at place that away from grid connected. Maybe some improvement can make to suit this system for used in the building.

ACKNOWLEDGMENTS

Many people contributed to these final year project. I would like to thank all lecturer especially my supervisor Dr. Muhammad Nabil Hidayat who put the effort to support me finish this research. The guide and support that he gave truly help the progression and smoothness of my research.

My grateful thanks also go to all member in CIDET group at the same time during discussions were held to share knowledge each other.

Great deals appreciated go to the staff of Green Energy Research Centre (GERC) and high voltage laboratory. Majority of my experiment was doing at GERC laboratory. All staff of GERC laboratory gives me a lot of help which concern about the equipment that I had used and give me comfortable place to do my experiment. I also uses high voltage lab that which is the main headquarters for CIDET. My thank also contribute to my faculty, Faculty of electrical engineering (FKE)

Last but not least I would like to thank my friends especially those who work together as one team under one supervisor are Mohamad Saiful Bin Mohd Yusup, Fadhli B Abdull Patah, Nur Izzati Bt Abdul Aziz, Nuranisah Bt Mohamad and Raihan Bt Azlan Sukhaizat.

REFERENCES

[1] The infinite power of Texas, "ELECTRICITY FROM THE SUN", The Texas State Energy Conservation Office and the U.S. Department of Energy, 2003, pg 5.

[2] Sydney Sanchez and Scott Sweeney, "LED vs T5 Technology: The Advantages and Disadvantages", Department of Research and Writing of lumiversal, 2010, pg 4.

[3] Tracy Empson, "This Little Light of Mine: Understanding Light Bulbs", Earth Day Network, 2008, pg 5.

[4] Prof. Madya Dr. Ahmad Maliki Omar, "INTRODUCTION OF PV SOLAR" Green Energy Research Center (GERC), Uitm Shah Alam, 2012.

[5] Joseph R. Woodworth, Michael G. Thomas, John W. Stevens, Steven R. Harrington, James P. Dunlop, M. Ramu Swamy, Leighton Demetrius, "EVALUATION OF THE BATTERIES AND CHARGE CONTROLLERS IN SMALL STAND-ALONE PHOTOVOLTAIC SYSTEMS", IEEE Photovoltaic Specialists Conference, 1994, pg 1-2.

[6] Lighting system, disadvantages of incandescent lamps, Available: http://elpaso.apogee.net/lite/lindisi.asp.

[7] Prof. Madya Dr. Ahmad Maliki Omar, "standalone PV system" green energy research center (GERC), uitm shah alam, 2012.

[8] Batteries, available: http://www.voltinmotion.com.

[9] 20Watts,12V Monocrystalline Panel, Arcman Solar Power, Available:http://www.arcmansolar.com/products/59.aspx?cid=7-12-11.

[10] BP SX10 Solar Panel / Multimount Frame, Available:http://www.solarelectricsupply.com/Solar_Panels/BP-Solar/BP_SX10.html

[11] Antonio Luque & Steven Hegedus, "Handbook of PHOTOVOLTAIC SCIENCIE AND ENGINEERING", John Wiley & Sons, Ltd, second edition 2011.

[12] Ned Mohan, Tore M. Undeland, Willian P. Robbins, "POWER ELECTRONICS", JOHN WILEY & SONS, ING, second edition 1995.