

**DESIGN AND DEVELOPMENT OF LIGHT CURRENT VOLTAGE  
(LIV) MEASUREMENT SYSTEM FOR SOLAR CELL BASED ON  
MICROCONTROLLER**

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(LIV) MEASUREMENT SYSTEM FOR SOLAR CELL BASED ON  
MICROCONTROLLER**

**BY**

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## LIST OF ABBREVIATIONS

PV	Photovoltaic
DC	Direct Current
A	Ampere
k	Boltzmann's constant
T	absolute temperature
q	elementary charge
$\eta$	Efficiency
AM	Air mass
$^{\circ}\text{C}$	Celsius degree
W	Watts
I	Output current
$I_L$	Photogenerated current
$I_D$	Diode current
$I_{SH}$	Shunt current
$I_0$	Reverse saturation current
n	Diode ideality factor

# **REKAAN DAN PEMBANGUNAN SISTEM PENGUKURAN**

## **CAHAYA ARUS VOLTAN (LIV) UNTUK SEL SURIA**

### **BERDASARKAN PENGAWAL-MIKRO**

#### **ABSTRAK**

Kelebihan dan peningkatan teknologi hijau telah meluas di seluruh dunia. Ini telah menarik minat kerajaan untuk melabur dalam sektor ini dimana bilangan yang ketara kapasiti tenaga suria telah dipasang. Ini akan menyediakan sumber tenaga alternatif dalam masa yang sama untuk mengurangkan pergantungan terhadap fosil bahan api yang diimport. Permintaan pengkomersilan untuk teknologi suria meningkat selari dengan permintaan penguji photovoltan cahaya arus voltan (LIV). Penguji LIV digunakan untuk menguji dan mengesahkan prestasi peranti photovoltan melalui Penguji ciri-ciri lengkungan LIV dan parameter sel photovoltan. Penguji LIV digunakan secara meluas dalam penyelidikan dan pembangunan, perindustrian serta dalam aktiviti perdagangan. Penguji LIV yang boleh didapati secara komersial terlalu mahal untuk dimiliki. Kajian ini adalah satu usaha untuk mereka dan membangunkan kos rendah penguji cahaya arus voltan (LIV) sistem berdasarkan pengawal-mikro. Penguji ini yang direka dikendalikan berhampiran dengan piawaian ujian keadaan (STC) bagi mengukur peranti photovoltan. Piawaian ujian keadaan (STC) diuji pada suhu sel suria 25 °C, sinaran suria pada 1000 W/m<sup>2</sup> atau keamatan sinaran suria bersamaan satu matahari dan jisim udara 1.5 (AM1.5) spektrum. Daripada penguji I-V percanggahan dan ralat didapati kurang dari 4% untuk kedua voltan litar terbuka dan litar pintas semasa. Walau bagaimanapun, percanggahan kuasa maksimum mencapai kira-kira 21% kerana arus dan voltan mendapat rendah dari yang dijangka. Ini berlaku kerana faktor rintangan dalam sambungan wayar dan komponen dan ketepatan setup sinaran LED.

# **DESIGN AND DEVELOPMENT OF LIGHT CURRENT VOLTAGE (LIV) MEASUREMENT SYSTEM FOR SOLAR CELL BASED ON MICROCONTROLLER**

## **ABSTRACT**

The advantage and improvement of green technology have been widespread all over the world. This has attracted the interest of the government to invest in this sector in which significant solar power capacity had been installed. This will provide an alternative energy sources and at the same time reducing the dependency on expensive imported fossil fuels. The demand for solar technology increases in parallel with the demand of photovoltaic light current voltage (LIV) tester. LIV testers are used to test and verify performance of Photovoltaics devices through LIV curve characteristics and photovoltaic cell parameters. The LIV tester was used extensively in research and development, industrial as well as in commercial activities. The existing LIV testers that were available commercially was too expensive to own. This research is an attempt to design and develop low cost light current voltage (LIV) measurement system based on microcontroller. The tester will be designed and operated close to the standard test condition (STC) for measuring photovoltaic device. The STC test conditions are testing temperature of the sample at 25°C, Solar Irradiance at 1000 W/m<sup>2</sup> or solar irradiation intensity of 1 Sun and air mass of 1.5 (AM1.5) spectrum. From the measurement of designed I-V tester gained discrepancy or error of less than 4% for both the open circuit voltage and short circuit current. Despite of that, the maximum power discrepancy reaches about 21% because the current and voltage gained were lower than expected result. This happen because factors of resistance in wires connection and components and accuracy of LED irradiance setup.

# CHAPTER 1

## INTRODUCTION

### 1.1 Overview

There are several ways human can generate electrical power from other sources of primary energy using the power generation plant such as hydraulic, wind, geothermal, nuclear and chemical. Nowadays, many industries tried to use solar Photovoltaics to generate electricity. Photovoltaics devices converted the sunlight directly into electricity through the process known as the photovoltaic effect. Due to the sunlight considered as a source of endless energy, this has led to the primary interests in solar cell research by several research groups worldwide. As a result, there were lots of R&D activities globally for the development of future-generation PVs and conduct fundamental research on conventional solar cell technologies [1].

Photovoltaic effect is the creation of voltage or electric current in a material upon exposure to light and is a physical and chemical phenomenon [1,19,20]. The photons in sunlight hit the solar panel and are absorbed by semi-conductor materials. Electrons which is negatively charged are knocked loose from their atoms as they are excited. Due to their special structure and the materials in solar cells, the electrons are only allowed to move in a single direction. The electronic structure of the materials is very important for the process to work, and often silicon incorporating small amounts of boron or phosphorus is used in different layers. An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity [4].

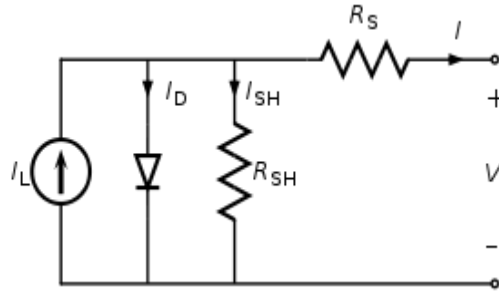


Figure 1.1: The equivalent circuit of solar cell in an ideal condition.



Figure 1.2: The schematic symbol of solar cell.

An ideal solar cell may be modelled by a current source in parallel with a diode as shown above but in practice no solar cell is ideal, so a shunt resistance and a series resistance component are added to the model [2].

Testing cell efficiency is not only important for control of the manufacturing process, but it is also required in the following steps to assemble the cells into panels. The efficiency of module determines the area of a module given the same rated output which mean that less efficient solar panel will take a slightly larger space than a more efficient solar panel if there is one panel is less efficient than another. By using more efficient panel will lead to a higher installed capacity and eventually generated more electricity.

To measure the cell efficiency for the solar cell, the light current voltage (LIV) measurement system will be designed and built. The efficiency test will be conducted at STC conditions that will generate an I-V performance curve as shown below.

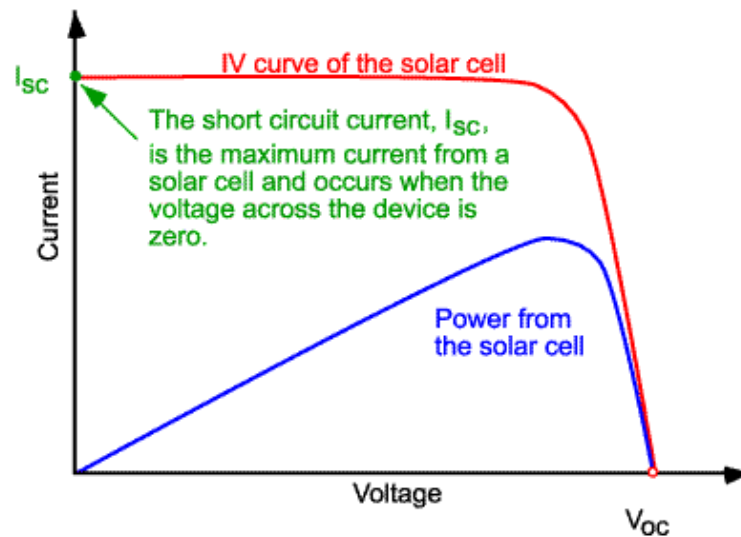


Figure 1.3: I-V characteristic and power curve of the solar cell.

In developing a solution for the client, it was critical that the measurement of performance of the test not to be compromised. The existing solar cells testers in market are expensive and can reach more than \$2000 USD per unit. Furthermore, it needs some proper skills in setting up and handling the device.

Year after year, solar energy technology becomes more advanced and the solar cell I-V testers were designed and built to test and verify the efficiency and performance of the solar cells. Many solar cell manufactures and institutes have established a research and development testing facility to test and verify solar cells performance. In this project, a prototype of the light current voltage (LIV) measurement system will be developed based on microcontroller. The goal is to have low cost LIV testing system that has reliable measurement result for research and development, industry and commercial activities.

## **1.2 Problem Statement**

The real problem of the existing IV tester sold in market is really expensive. The testers were usually imported from overseas thus making maintenance works difficult. To overcome this problem, the light current voltage (LIV) measurement system for solar cell will be designed and built using a microcontroller in simple ways and easy to use. Even though it is simple but the capability to accurately measure high-efficiency conventional or backside-contact of solar cells of the product will be almost the same comparing with manufacture solar I-V tester to ensure the successful of the project.

### 1.3 Objective

The objectives of this project are:

1. To study and investigate the light current voltage (LIV) measurement system for solar cell.
  - This motivation of study is to analyze the behaviors and reaction of solar cell after absorbing the sun radiation through the silicon.
2. To design and develop the LIV measurement system for solar cell performance based on microcontroller.
  - The making of simpler and easy handling I-V tester from the industrial product.
3. To compare the I-V characteristics measured from I-V tester with actual data from manufacture solar.
  - The standard measurement system had been uses for solar cell before distribute among customers. At the end of project, the data will be compare for further investigation.

## 1.4 Scope Project

In this modern era, the solar power may need by industry because of the long lasting natural sources. To make sure that the solar cell is in top condition the solar cell tester is needed to measure the efficiency and I-V characteristics of the cell. The scope of this project will be focus on designing and building the light current voltage (LIV) measurement system for solar cell based on microcontroller.

The tester will detect the light and measure the current and voltage produce by the solar cell. All of the data needed will be recorded and from the data the I-V curve can be drawn. Solar cells produce direct current (DC) electricity and the solar cell I-V curves representing the current versus the voltage characteristic for the measured photovoltaic device.

Solar Cell I-V Characteristics Curves are basically a graphical representation of the operation of a solar cell or module summarizing the relationship between the current and voltage at the existing conditions of irradiance and temperature. I-V curves provide the information required to configure a solar system so that it can operate as close to its optimal peak power point (MPP) as possible as shown in I-V characteristics curve before [3,5].

## **1.5 Outline Report**

This thesis consists of five main chapters described and explain the full details from introduction to conclusion of this project. The first chapter is about the introduction of this project which is review and discuss the principle of fundamental solar cell including description on the project background, problem statement, objective, scope and outline of the report.

Chapter 2 is about literature review of the past works done related to the project. This chapter discuss about the covered summary of the relevant topics about the basic solar cell and the light current voltage (LIV) measurement system from previous studies compile into books projects. It is also review the solar cell I-V characteristic curve and its parameter measurements.

In chapter 3, the methodology is discussed and states all the process taken to complete this project. Flowchart of process taken are elaborated including the method of calculating the light current voltage (LIV) measurement use in this project. Furthermore, the microcontroller is covered in this chapter in connectivity and coding aspects.

Chapter 4 is the important part which is where all the result to the features and the characteristics calculated for the system will be shown and brief. Moreover, the result may be converted to the graph either using LCD or simulation called solar cell I-V characteristic curve.

The last chapter, chapter 5 will presents the achievements of the project objectives given and conclude the whole project. This chapter also covered the limitation of the system and the future works for improvement.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

The increment energy demand and the fast depletion of fossil fuels have prompted the world to look for alternative source of energy. The solar energy technologies which harness the sun's energy to produce the electricity become the fastest growing sources of renewable energy in all over market nowadays. This chapter presents the relevant review from the recent and past literatures related to the basic concept of solar cell, light current voltage (LIV) measurement system components and characteristics including the design challenges based on previous thoughtful of other researches and studies.

#### **2.2 Light Current Voltage measurement**

The Solar system or photovoltaic (PV) cell converted illuminated radiation into electrical power. When the solar cell is illuminated, optically generated carriers produce an electric current that flows when the cell is connected to a load. To determine the electrical characteristics of PV cells the Current Voltage (IV) Measurement is used and done at standard test condition. Important device parameters can be extracted from the current-voltage (I-V) measurements, such as the conversion efficiency and the maximum power output.

## 2.3 I-V characterization of Solar or Photovoltaics (PV) cells

### 2.3.1 Equivalent circuit and characteristic equation

Photovoltaic energy conversion in solar cells consists of two essential steps. First, absorption of light generates an electron hole pair. The electron and hole are then separated by the structure of the device (electrons to the negative terminal and holes to the positive terminal) thus generating electrical power [5]. An ideal solar cell may be modeled by a current source in parallel with a rectifying diode but in practice no solar cell is ideal, so a shunt resistance and a series resistance component are added to the model shown as in figure below [4,5,9].

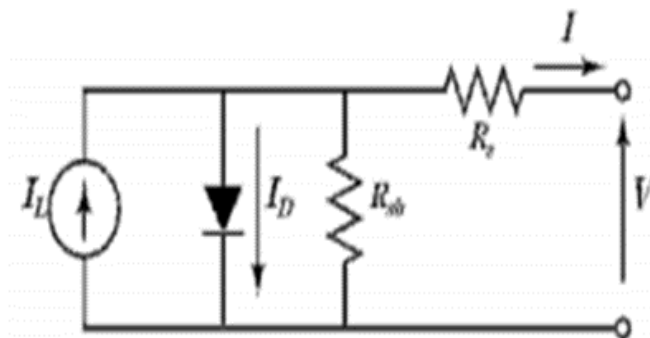


Figure 2.1: A single diode with series and parallel resistance equivalent circuits [16].

From the equivalent circuit, the current produced by solar cell is equal to:

$$I = I_L - I_D - I_{SH}, \text{ where} \quad (2.1)$$

$I$  = output current

$I_L$  = photogenerated current

$I_D$  = diode current

$$I_{SH} = \text{shunt current} = \frac{V + I_{RS}}{R_{SH}}$$

The diode current equation is given by,

$$I_D = I_0 \left\{ e^{\frac{qV_D}{nkT}} - 1 \right\} = I_0 \left\{ e^{\frac{q(V + I_{RS})}{nkT}} - 1 \right\}, \text{ where} \quad (2.2)$$

$I_0$  = reverse saturation current

$n$  = diode ideality factor (1 for an ideal diode)

$q$  = elementary charge

$k$  = Boltzmann's constant

$T$  = absolute temperature; at  $25^\circ\text{C}$ ,  $\frac{kT}{q} \approx 0.0259 \text{ volts}$

The other way to write the characteristic equation of a solar cell is,

$$I = I_L - I_0 \left\{ e^{\frac{q(V + I_{RS})}{nkT}} - 1 \right\} - \frac{V + I_{RS}}{R_{SH}} \quad (2.3)$$

### 2.3.2 Solar Cell I-V Characteristic Curve

The IV curve of a solar cell is the superposition of the IV curve of the solar cell diode in the dark with the light-generated current [7]. It is a detailed description of its solar energy conversion ability, efficiency and output performance information that shows in a graphical representation [8].

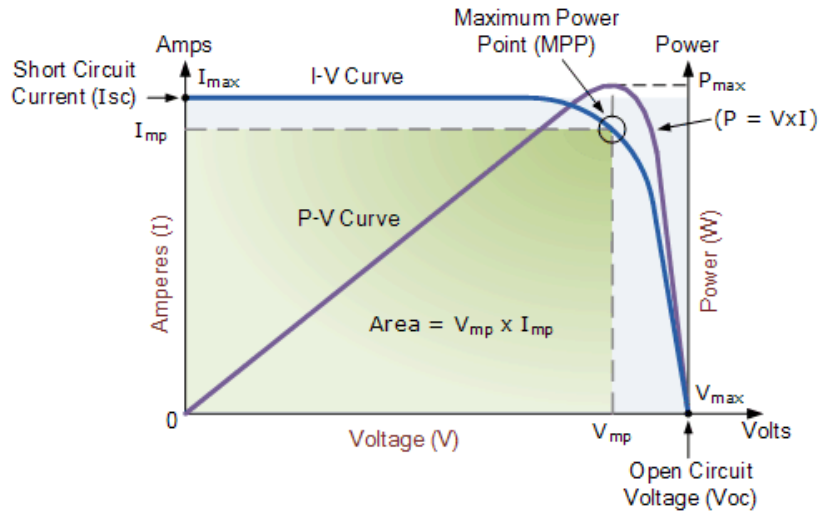


Figure 2.2: I-V and P-V characteristic curve [14].

The above graph shows the current-voltage (I-V) and power- voltage(P-V) characteristics of a typical silicon solar cell operating under normal conditions. The power delivered by a solar cell is the product of current and voltage ( $I \times V$ ).

### 2.3.3 Solar Array Parameter Measurements

#### 2.3.3.1 Open-circuit voltage (VOC)

The condition of maximum voltage that the solar provides when the terminals are not connected to any load. This value is much higher than  $V_{mp}$  which relates to the operation of the PV array which is fixed by the load. This value depends upon the number of PV panels connected together in series. Assuming the shunt resistance is high enough to be neglected in the characteristic equation (2.3), the open-circuit voltage VOC is

$$V_{OC} \approx \frac{kT}{q} \ln \left( \frac{I_L}{I_0} + 1 \right) \quad (2.4)$$

### **2.3.3.2 short-circuit current (Isc)**

The condition of maximum current provided by the PV array when the output connectors are shorted together. This value is much higher than  $I_{mp}$  which relates to the normal operating circuit current.

### **2.3.3.3 Maximum power point (MPP)**

Maximum value when the power supplied by the solar connected to the load (batteries, inverters), where  $MPP = I_{mp} \times V_{mp}$ . The value of maximum power is measured in Watts (W) or peak Watts (Wp).

### **2.3.3.4 Fill Factor (FF)**

The relationship between the maximum power that the solar can actually provide under normal operating conditions and the product of the open-circuit voltage times the short-circuit current, ( $V_{oc} \times I_{sc}$ ). This fill factor value gives an idea of the quality of the solar and the closer the fill factor is to 1 (unity), the more power the solar can provide. Typical values are between 0.7 and 0.8.

$$FF = \frac{P_m}{V_{OC} \times I_{SC}} = \frac{V_{mp} \times I_{mp}}{V_{OC} \times I_{SC}} \quad (2.5)$$

### 2.3.3.5 Efficiency ( $\eta$ )

The ratio between the produced maximum electrical power with the amount of solar irradiance hitting the solar. Normally depending the type of cell like monocrystalline, polycrystalline, amorphous or thin film the efficiency of a typical solar array low at around 10-12%. Efficiency also depend on solar spectrum, intensity of sunlight and the temperature of solar cell [15]. Mathematically, it is the maximum power point ( $P_m$  in W/m<sup>2</sup>) divided by the input light irradiance ( $P_{light}$  in W/m<sup>2</sup>) [12].

$$\eta = \frac{P_m}{P_{light}} \quad (2.6)$$

### 2.3.3.6 Series resistance ( $R_s$ )

The voltage drop across  $R_s$  depends on the extracted current and can significantly reduce the terminal voltage. When the series resistance increases, the voltage drop across the junction voltage and the thermal voltage becomes greater with the same current and its lead to the significant decrease in terminal voltage,  $V$ . At high  $R_s$  the series resistance dominates and the behaviour of the solar cell resembles that of a resistor. The power losses can be calculated using the approximated equation:

$$P_{LOSSES} = V_{RS} \times I = I^2 \times R \quad (2.7)$$

It can be seen that losses by series resistance are the most important at high illumination intensities.

### 2.3.3.7 Shunt resistance (Rsh)

The infinite shunt resistance will give the perfect and ideal solar cell and not provide an alternative path for current flow while  $R_s$  is zero. There will be no further voltage drop before the load. As the shunt resistance decreases, the current diverted through the shunt resistor increases for a given level of junction voltage. The voltage controlled portion of I-V starts to sag towards the origin producing significant decrease in the terminal current. Low values of shunt resistance will make reduction in  $V_{OC}$ .

The figure shown below the effect of fill factor (FF) and  $P_{max}$  by diverging the internal resistance  $R_s$  and  $R_{sh}$ .

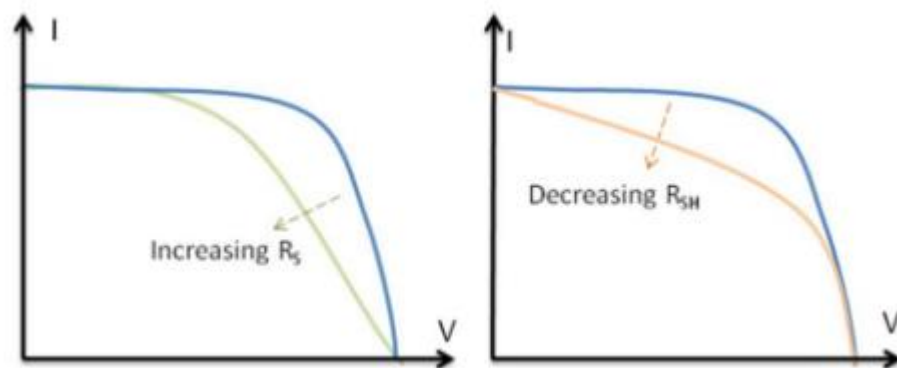


Figure 2.3: Effect of diverging  $R_s$  &  $R_{sh}$  from Ideality.

## **2.4 Standard Test Conditions (STC)**

It is the output performance testing condition for solar panel of crystalline silicon and thin film PV module used by most manufactures and testing bodies to ensure the standardize of output evaluation of different solar PV modules.

This standard is used to 3 specific fixed condition as temperature of the cell itself not temperature of the surrounding must be 25°C, Solar Irradiance at 1000 Watts per square meter or solar irradiation intensity of 1 Sun and lastly an air mass of 1.5 (AM1.5) spectrum [6]. In the manufacturing process STC requirements there are cases that STC requirement does not diligently met by the manufactures internal quality control such as with frequent deviations in lamp spectrum, cell and environment temperature, irradiation and etc.

## **2.5 Illumination Source**

In order to measure the solar cell a stable light source that closely matches the conditions of sunlight is required. Sunlight itself is an obvious option when come to this but to get stable condition for all the time is impossible because it depends on the weather. The spectrum also taken into the account because it may be change throughout the day and this further limits the time for testing. The solution nowadays is use artificial light source that simulates the sun. The ideal illumination source would have following features [10]:

1. A spatial non uniformity of less than 1%.
2. A variation in total irradiance with time of less than 1%.
3. These requirements are essential in obtaining an accuracy of better than 2%.
4. Filtered for a given reference spectrum to have a spectral mismatch error of less than 1%.

Even though the solar cell tester follows the specific condition for standardize but the real thing is to make a light source that exactly matches the AM1.5 spectrums and with the necessary illumination intensity is really tough and difficult. However, these are method to compensate for the differences of the device under test which measure the spectral response then use that to correct for the known difference between the spectrum of the light source and the standard spectrum. Solar simulators are classified according to spectral match, irradiance inhomogeneity (spatial uniformity over the illumination area) and temporal instability (stability over time) and their classification is shown in Table 2.1 where class-A is the best rating [17].

Table 2.1: Solar simulator classification according to IEC 60904-9 Ed. 2.0.

Class	Spectral Match	Irradiance Inhomogeneity	Temporal Instability	
			Long Term	Short Term
A	0.75 - 1.25%	2%	0.5%	2%
B	0.6 - 1.4%	5%	2%	5%
C	0.4-2.0%	10%	10%	10%

## **2.6 Temperature on solar cell**

There are disadvantage comes when using the continual artificial light source (solar simulator) in taking the I-V measurement where the rise of temperature of sample cell and resulting the inaccurate  $V_{oc}$  determination. The solar panel work best in certain weather condition and it is important to know the temperature of solar cell to predict its power output.

### **2.6.1 Effect of temperature on I-V measurement**

On of issue like the ambient temperature plays an important role in the photovoltaic conversion process [12,21]. Solar panel efficiency is affected negatively by temperature increases because of heat absorption by the solar panel. The temperature most significantly affects  $V_{oc}$  in the characteristic equation of solar cell (2.3) As the temperature of the solar cells rising, the current rises very slightly, but the voltage decreases more rapidly [13]. So the output power decrease with increasing of temperature. The solar panel that sensitive to the heat can reduces their production of power with reduce output efficiency by 10-25%.

## 2.7 Effect of Light Intensity on solar cell

Eventually by changing the light intensity the solar parameter also changes. All of this also will change the short-circuit current ( $I_{sc}$ ), the open-circuit voltage ( $V_{oc}$ ), the Fill Factor (FF), the efficiency and the impact of series and shunt resistances. At low light where the light intensity continually decreases, the current through the solar cell also decreases, and the equivalent resistance and shunt resistance of solar cell maybe the close and become similar. When that happen there will be increasing of the total current flowing through the shunt resistance, then the fractional power loss also increases due to shunt resistance behaviour. Consequently, under cloudy conditions, a solar cell with a high shunt resistance retains a greater fraction of its original power than a solar cell with a low shunt resistance [11].

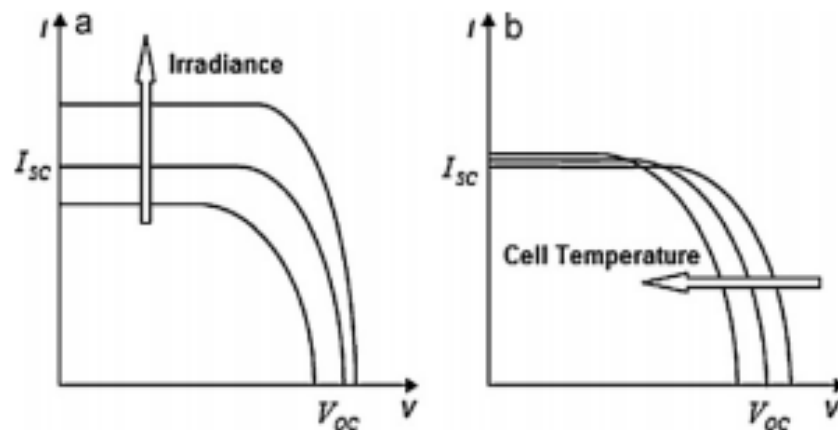


Figure 2.4: Effects of irradiation and cell temperature on PV cell characteristic  
(a) effect of increased irradiance and (b) effect of increased cell temperature [13]

## 2.8 Ideality factor

The ideality factor describes the diode's behaviour and how closely that matches to the theory's assumption [17]. Under STC rule the ideality factor,  $n = 1$  when the diode's behaviour fully complies the ideal theory which assuming that p-n junction of the diode is an infinite plane. Besides, no recombination within the space-charge region. Based on the derivation of the ideal diode equation below the ideality factor,  $n$ , is equal to one can be found.

$$I = I_L - I_0 \left\{ e^{\frac{qV}{nkT}} - 1 \right\} \quad (2.8)$$

There are several practical problems when measuring ideality factors [17]:

1. At low voltages the shunt resistances ( $R_{shunt}$ ) dominates the device performance and causes a large peak. It is usually not possible in practice to correct for the effects of  $R_{shunt}$ .
2. At high voltages in a dark-IV curve the series resistance dominates and this causes a large peak in the ideality factor curve at high voltages. This can be alleviated by using the Suns-Voc curve that as noted earlier gives a curve the same as dark-IV but without the effects of series resistance.
3. The ideality factor comes from the differential of a signal so it is very prone to noise. Noise problems are particularly problematical in Suns-Voc measurements. To reduce noises, the slope is usually taken as a fit over several points.
4. The effects of temperature are a problem particularly if the temperature change during the measurement.

## 2.9 Manufacture I-V Tester Product

In industrial market the product of the photovoltaic I-V curve tester already launches by some companies worldwide in portable ways and low cost where can operate even outside enclosed room to judge the performance of solar cell. The Table 2.2 below shown the comparison between three different brand products in several criteria.

The product SOLAR I-V that had been design and launch by HT Italia company also provided with the remote unit SOLAR-02 for measuring irradiation and temperature. The measured I-V characteristic is not affected by the resistance of measurement cable, as it carried out with the 4-terminal measuring method. The measured values correctly reported at standard test condition, are immediately compared with the values declared by the manufacturer to give the OK or NO result of the test.



Figure 2.5: Manufacture solar tester SOLAR I-V by HT Italia.

Second product is PV Analyzer PROVA 200A by PROVA company that suitable for quality control in the production line, warehouse, or site of installation which identify the solar power system requirement. Furthermore, it is ideal for searching for possible failures and problems in systems is extremely rapid, efficient and intuitive.

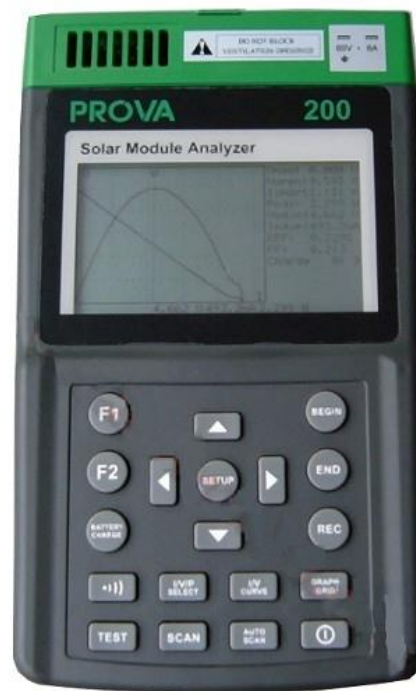


Figure 2.6: Manufacture solar tester PV Analyzer PROVA 200A BY PROVA.

Next product is SOLAR-500 Solar Analyzer Test Solar Panels by Amprobe company that professional analyser used for testing, maintenance, troubleshooting and efficiency of solar panels. It is also used in the installation of solar panels to determine the proper inverter size, optimum power output position of panels and identifies broken or worn-out cells.



Figure 2.7: Manufacture solar tester SOLAR-600 Solar Analyzer Test Solar Panels by Amprobe.

Table 2.2: Manufacture solar I-V tester comparison in market nowadays by different companies (a) HT Italia (b) PROVA (c) Amprobe

<b>CRITERIA</b>	<b>SOLAR I-V</b>	<b>PROVA 200A</b>	<b>SOLAR-500</b>
Price	US \$ 4995.00	US \$ 892.71	US \$ 1755.95
Voltage Range	0 – 1000 V	0 – 60 V	0 – 60 V
Current Range	0 -10 A	0 -6 A	0 -6 A
Max. Power Rating	10kW	180 W	180 W
Weight	1200 g	1160 g	1160 g

The I-V tester that will be develop in this project based on this concept of manufacture product iv Solar X6 Steady-state Solar Simulator. This product consists of three systems which is lamp house, lamp power and operating instruction. The price of this type of solar tester manufacture product are much times over compare to the portable products list before because its complexity.

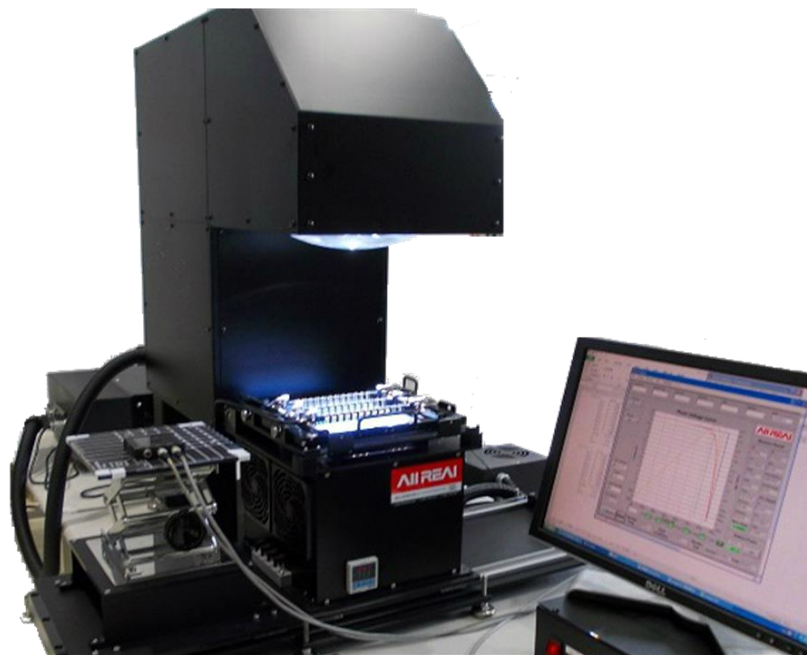


Figure 2.8: Manufacture solar tester SOLAR-600 Solar Analyzer Test Solar Panels by Amprobe.

## **CHAPTER 3**

### **METHODOLOGY**

#### **3.1 Introduction**

From the previous chapter, the concept of the solar cell and its characteristics had been peel off from tons of researches done on solar energy. To achieve the objective of this several topics will be discussed and explained in details.

This chapter consist of three parts which are the project requirement that based on hardware and software. All the components that are used in this project available commercially. Second part is possibility of various design of the project that had been implement to ensure the successful objective. Lastly is collection of data and analysis based on the project requirement.

Each part will be discussed in detail and compare with others possibility to verify the best output. Briefly, the system will start with the solar cell absorbing of artificial light source under STC condition. The data will be collected and save to drawn the graph of I-V and P-V curves along with required data.