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The effectiveness of a mini photovoltaic cell by using light LED bulbs as a source of photon energy

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Abstract. Muxindo's LED bulb is one of the brands that are widely used by Indonesian people as lighting in the home. This study aims to look at the effectiveness of the light spectrum of the 10, 15 and 20 Watt LED power bulbs as an energy source to generate electrical energy in monocrystalline mini photovoltaic (PV) cell module. The light spectrum is compared with and without the Fresnel lens before being transmitted to the PV surface. The test results show that the PV output power is much better with a Fresnel lens (4.06> 1.67) mW. The efficiency of PV with lens displays slightly different figures, 3.77% at 15 Watt bulb power, while without Fresnel lenses, PV efficiency is 4.86% with a 20 Watt bulb. Need further research, for example, with Philips brand LED bulbs

1. Introduction

Sunlight has a high enough intensity and complete spectrum for the needs of living things on this earth. This spectrum can be utilized to be converted into electrical energy with the help of photovoltaic cell technology. The spectrum is a combination of several colors that emit electromagnetic waves which have a specific wavelength and are divided into 3 main categories; ultraviolet, visible spectrum and infra-red (Near and far infrared-NiR / FiR). Only the spectrum in the visible ranges has photons with wavelengths around 400-760 nm [1]. However, in laboratory-scale testing, sunlight is difficult to use because its wavelength is unstable or its intensity changes according to the Earth's rotation. The bulb spectrum that is classified as artificial lights [2] is an alternative photon energy for photovoltaic (PV) because it has a spectrum similar to sunlight. Several studies related to the spectrum of sunlight such as Ali et al., [3], and Evaldo et al., [4], with artificial lights, Bach [5], Apostolou et al. [6] and Mustofa et al. [7]. Furthermore, in a PV simulation Daniel and Hariyanto [8] used a Fresnel lens to focus the AM1.5G solar radiation spectrum with a Matlab simulink. Deming et al. [9] used a holographic lens to increase the concentration and conversion of PV energy.

Interesting research that manipulates the spectrum of light by using an absorbent layer on the lens that splits the visible and thermal spectrum by Stanley et al. [10]. Researchers conducted with several concentrator models and the formation of spectrum dimensions from the sun. It is necessary to characterize the PV cell of the spectrum formation. Meanwhile Bliss et al. [11] in detail describes the use of types of photon energy source bulb spectra especially LED, CFL and incandescent bulbs for indoors scale PV cells. However, this study did not show the effect of the bulb spectrum on the performance of PV cells as an indicator of the effectiveness of the electrical energy generated by cells. They describe the advantages of LED bulbs in sun simulators for PV compared to other types of conventional bulbs, because

LEDs last longer with wavelengths at 375-680 nm intervals. To provide a more detail of one type of cool white LED bulb on the performance of PV cells and visible spectral emissions, this study uses a variety of light bulbs with either a light spectrum concentrator in the form of Fresnel lens or without lens.

2. Materials and Methods

In this study, 10, 15 and 20 Watt power LED bulbs are used as visible spectrum sources. Then the visible spectrum is concentrated using a polymethylmethacrylatea (PMMA) Fresnel lens with dimensions of 112 x 73 mm^2 with a focal length of 110 mm. The lens transmission spectrum is equal to 92% [12]. PV module with specifications of 0.6W, 5.5V, and 90mA monocrystalline with dimensions of 65 x 65 mm^2. The test design is shown in Figure 1, where A is a terminal block for reading voltage and current of PV cell. B is the testing set-up and C is V and I multimeter digitals.

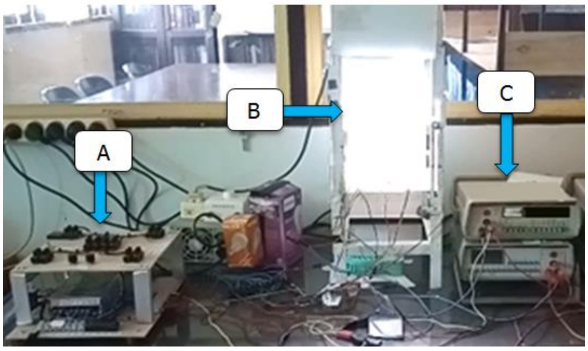


Figure 1. Experimental set-up

The LED bulb was mounted inside a specially designed box with dimensions 215 × 215 × 425 mm. The lamps were placed at a distance of 500 mm from the base of the box. The spectrometer was placed inside the boxes, so that ambient light from the outer box could not affect the measurements. The sensor of the spectrorameter was placed just above surface of the PV. The spectral irradiance of each lamp was measured using a mini USB spectrometer (Thunder Optic) which was connected to a computer using Spectragryph 1.2.14 software application as seen in Fig 2.

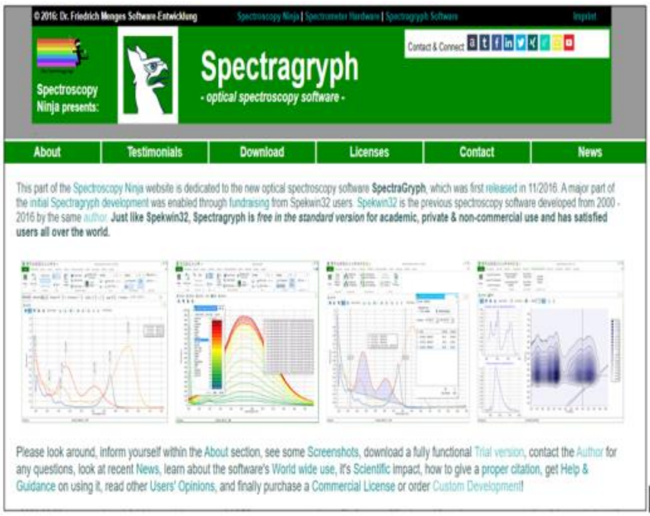


Figure 2. Spectragryph 1.2.14 [13]

Equation (1) and (2) give the general formula for the calculation of the efficiency η of a PV cell:

$$\eta_{PV} = \frac{P_{maks}}{P_{in}} = \frac{V_{oc} I_{sc} FF}{G A_{PV}} \quad (1)$$

Where $$FF = \frac{I_{mp} V_{mp}}{I_{sc} V_{oc}} \quad (2)$$

3. Results and discussion

3.1 LED bulb spectrums

Fig. 3 displays the Muxindo's LED spectral energy distribution bulb on the PV surface. This spectral energy is the result of degradation from the light bulb surface, after the Fresnel lens to just above the surface of the PV cell. The three spectral energy distributions feature 10, 15 and 20 Watt bulbs. It is clearly seen that the energy spectrum of the 15 Watt light bulb is the highest even though it appears almost all coincide. The difference in spectrum energy will be seen more clearly in the output power and efficiency of the PV cell. Fig. 3 also illustrates the formation of visible spectrum between 400 and 700 nm which is relatively low in intensity, so photon energy is also less optimal. This affects the photon energy received by the PV semiconductor to release the excitation of electrons to the hole. Spectral energy distribution used in this experiment is a type of cool white LED which is classified as less efficient compared to warm white LEDs [5].

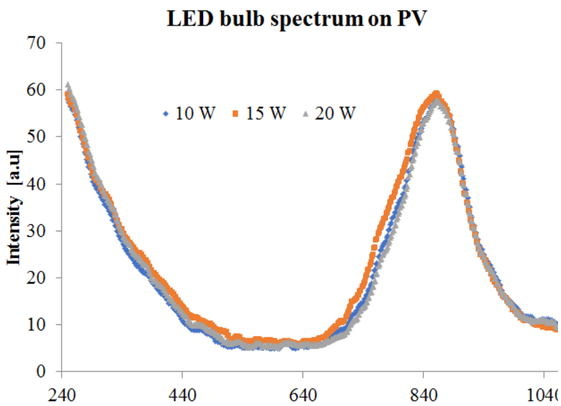
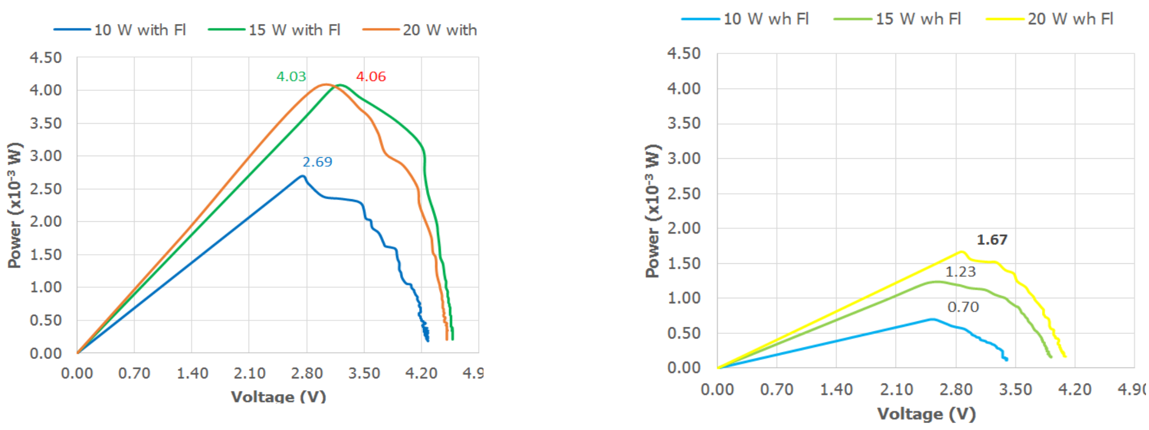


Figure 3. Spectral energy distribution of LEDs

3.2 P-V curve with and without Fresnel lens

By using a digital multimeters measuring device, the voltage and electrical power recorded with a PV cell are as shown in Figure 4. The LED bulb with a power of 15 Watt shows maximum power (4.06x10-3W) at a voltage of around 2.35 Volt. This figure is slightly better compared to 20 and 10 Watt power. One reason is that the external beam surface of the 15 Watt bulb is smaller and matches the dimensions of the Fresnel lens, so that the transmitted spectral energy is greater than the bulbs of 20 and 10 Watt. Unlike the PV power generated without a Fresnel lens, a 20 Watt bulb shows an optimal power of 1.67x10-3 Watt at the same voltage using a Fresnel lens (Fig. 4b).

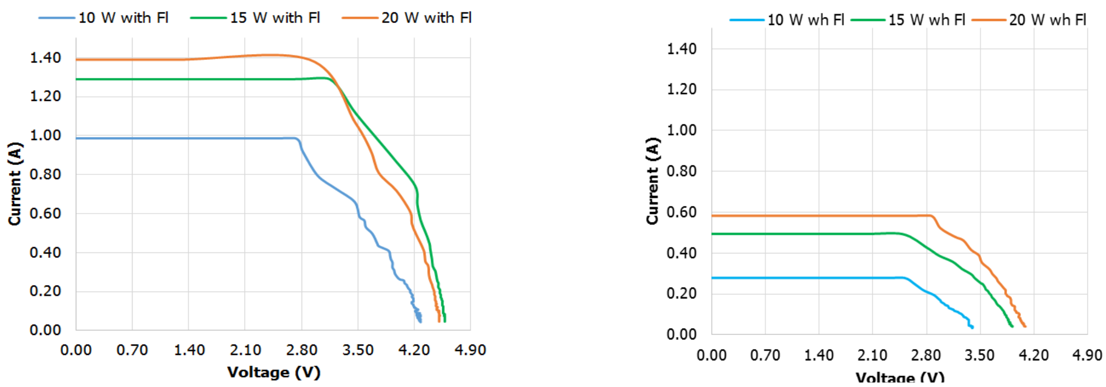


(a) (b)

Figure 4. P-V curves; (a) with Fresnel lens, (b) without Fresnel lens

3.3 I-V curve with and without Fresnel lens

Figure 5 illustrates a consistent trend, where the magnitude of the bulb is proportional to the increase in electric current generated by PV. This current tends to be flat up to the voltage of 2.80 Volts and then decreases sharply at around 4.30 Volts. The amount of electric current is 2 times better than without using a Fresnel lens.



(a) (b)

Figure 5. I-V curves; (a) with Fresnel lens, (b) without Fresnel lens

3.4. Efficiency of PV cell

When referring to the design conditions of this experimental device, the best efficiency is obtained by using a Fresnel lens from a 15 Watt LED light bulb spectral radiation at 3.77%. Without Fresnel lens, the 20 Watt bulb remains the best with 4.86% efficiency. The trend of increasing efficiency without a Fresnel lens looks regular with the magnitude of the bulb power (3.49; 4.10; 4.86)% ~ (10; 15; 20) Watt as depicted in Fig 6.

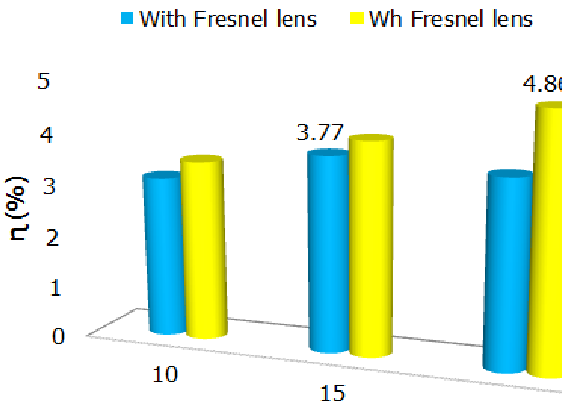


Figure 6. PV efficiecny using LED bulb lights

4. Conclusions

It can be concluded that the Muxindo brand small power LED bulb that is widely installed in people's homes has the potential to regenerate electricity in the form of the PV module photon energy spectrum. The Fresnel lens provides a good influence on the 15 Watt bulb power as a photon energy input. Conversely, the best 20 Watt power effectiveness if not using the lens. This shows that further testing of other types of bulb, such as Philips, is needed as a comparison.

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Nomenclature

a.u	arbitrary unit
A_{PV}	Area of photovoltaic cell
I_{sc}	current short circuit, (A)
I_{mp}	maximum power current, (A)
V_{mp}	maximum power voltage, (V)
V_{oc}	open circuit voltage, (V)

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LED	lighting emitting diode
Fl	Fresnel lens
FF	Fill factor
G	intensity
P_{maks}	Max Power, (W)
P_{in}	Input power, (W)
η_{PV}	Photovoltaic efficiency
PV	photovoltaic
P-V	power-voltage
I-V	current-voltage
wh	without