Effect of Solar ILLuminance (or Intensity) on Solar (Photovoltaic) cell's output and the use of Converging lenses and X or Gamma rays to enhance output performance

Joseph Amajama

Electronics and Computer Technology Unit – Physics Department – University of Calabar – Nigeria, joeamajama2014@yahoo.com
+234-7036357493

Abstract— The effect of solar illuminance (or intensity) on a photovoltaic panel has been examined. Illuminance is synonymous to light intensity. Illuminance is directly proportional to light intensity per square of the distance between the source of light and object. The solar illuminance (or intensity) within the weather parameters' ranges of 77 ^{o}F – 90 ^{o}F (air temperature), 30 inHg – 29.85 inHg (air pressure), 66 % and 89 % (relative humidity) and 5 mph – 10 mph (Wind speed), mainly in the WSW direction was measured and simultaneously the output current and voltage. The solar illuminance (or intensity) was measured with a Digital Illuminance Meter (DT-1309). The result spells that the current rises steadily with increase in solar illuminance or intensity. However, the rise rate reduces at a point with further increase in illuminance (or intensity), when the raining light excessively extract electrons (or holes), gradually resulting in collisions and a randomized flow, rather than the regular flow. The voltage output rises sharply with increasing illuminance (or intensity), but at a certain point attains the maximum level. Afterwards, the rate of change of the voltage with increasing illuminance (or intensity) becomes insignificant. The response curve at this point becomes steady. The current output of solar cells is polynomial while that of the voltage is logarithmic. The power output of the solar cell is directly proportional to the output current, regardless of that of the voltage under similar atmospheric conditions. The power output response curve takes the form of the current curve. Hence under similar weather conditions, provided that the capacity of a photovoltaic cell is not exceeded – $P = KIL^2$: where P is the power (Watt), I is the current (A), L is illuminance (Lux) and K is the loss or gain power factor depending on the photovoltaic cell. Also, since solar illuminance (or intensity) has a high positive effect on the solar cells, a good converging lens to focus solar radiations on the photovoltaic panel will enhance the efficiency of the output, most especially in regions of low sunlight. And, since the current is generated as a result of photoelectric effect: it is possible for higher energetic particles above the ultraviolent particles to extract and excite more electron or current than solar radiation (mainly visible light and ultraviolent particles) and improve output. This may be recommended for the Polar Regions. Gamma or X-ray particles may be incident on the photovoltaic panel.

Keywords— Effect, Solar illuminance, Solar intensity, Photovoltaic cell, Solar cell, Photovoltaic panel, Solar panel, Output, Performance, Converging lenses and X or Gamma rays.

INTRODUCTION

Luminosity is the rate of emission of radiation, visible or otherwise [1]. Illuminance in short, is the amount of luminous flux incident on a surface per unit area [2]. It is a measure of how much the incident light illuminates the surface, wavelength-weighted by the luminosity function to correlate with human brightness perception. The SI unit of illuminance is Lux. Illuminance was formerly often called brightness, but this leads to confusion with other uses of the word, such as to mean luminance. "Brightness" should never be used for quantitative description, but only for non-quantitative references to physiological sensations and perceptions of light. [3].

As a surface that is illuminated by a light source moves away from the light source, the surface appears dimmer. In fact, it becomes dimmer much faster than it moves away from the source. The inverse square law, which quantifies this effect, relates illuminance (E) and intensity (I) as follows: $E = I/d$; Where d = the distance from the light source. For example, if the illuminance on a surface is 40 lux (lm/m) at a distance of 0.5 meters from the light source, the illuminance decreases to 10 lux at a distance of 1 meter [4].

The sun radiates an overwhelming volume of energy onto the earth to meet the global energy demand for a whole year. Solar panels produce energy less than a tenth of one percent of the entire global energy demand. The panels are called photovoltaic cells which are found on things like spacecraft, rooftops, and calculators. The cells are made of semiconductor materials like those found in computer chips. When sunlight strikes the cells, it extracts and excites the electrons from their atoms. The electrons generate electricity as they flow through the cell [5].

Nearly every technological apparatus requires power for its optimal performance [6]. A solar panel can generate power with a four-piece battery system that can be filled with unfiltered water, and the battery can recycle water to generate battery or power. If three panels are put together, these can produce enough electrical energy to power a home with a family of four to eight people living within the structure it is powering [6]. It also allows a vehicle to run on solar power. In addition, a typical solar panel produces 200 watts of power or more. To power a building like a bank, for example, a five kilowatt-hour array, which is about 25 solar panels, is necessary [6]. The solar panels will absorb 1,000 watts of sunlight per square meter on the panels' surfaces. To power a high school building, a 6.25 megawatt capacity, equivalent to 24 solar panels, is needed [5].

Changing the light intensity incident on a solar cell changes all solar cell parameters, including the short-circuit current, the open-circuit voltage, the fill factor, the efficiency and the impact of series and shunt resistances [7] [8] [9]. The light intensity on a solar cell is called the number of suns, where 1 sun corresponds to standard illumination at 1 kW/m^2. Solar cells experience daily variations in light intensity, with the incident power from the sun varying between 0 and 1 kW/m^2. At low light levels, the effect of the shunt resistance becomes increasingly important [7]. As the light intensity decreases, the bias point and current through the solar cell also decreases and the equivalent resistance of the solar cell may begin to approach the shunt resistance. When these two resistances are similar, the fraction of the total current flowing through the shunt resistance increases, thereby increasing the fractional power loss due to shunt resistance. 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 [7] [10].

This object of this paper is to find the relationship between solar illuminance (or intensity) and the output of solar panels and make recommendations on how the output can be enhanced through the science from this paper.

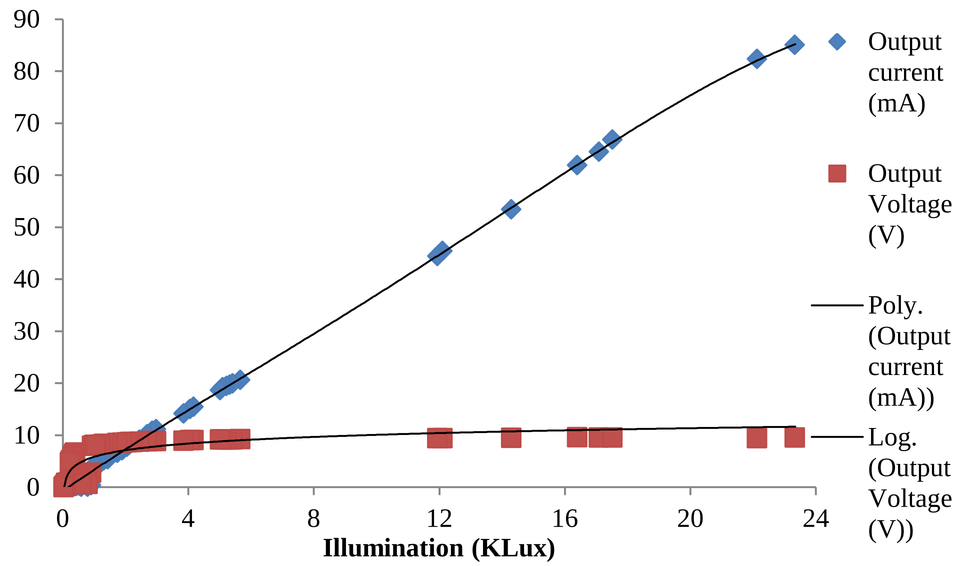
METHODOLOGY

Weather parameters: air temperature, air pressure, relative humidity and wind speed and direction were measured intermittently and simultaneously with solar illuminace and output voltage (open circuit voltage) and output current (short circuit current) of the solar panel.

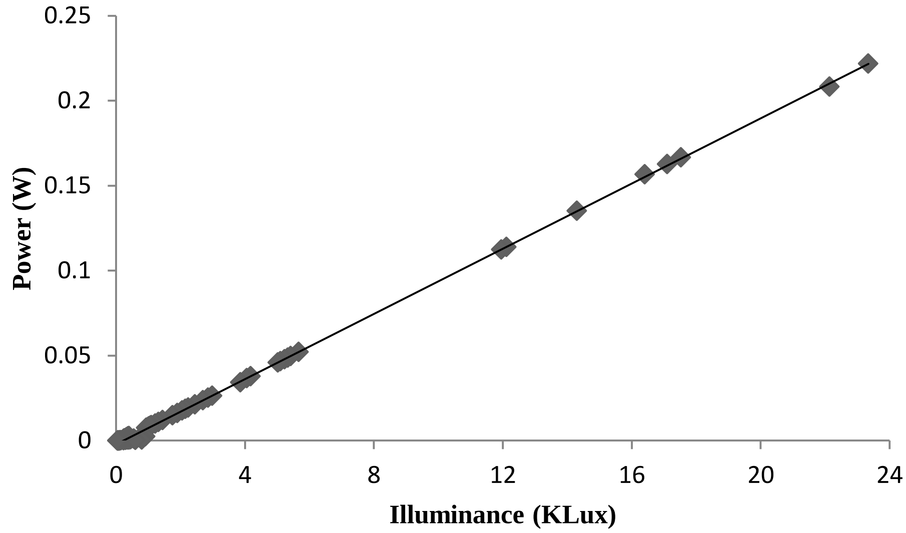
The solar panel is the mono-crystalline cell type with 1.5 W, 12 V rating. The dimensions of the solar cells' plate excluding the metallic frame of the panel is 45 cm by 14.5 cm. It was mounted on a platform of about 105 cm and exposed to direct sunlight. The outputs of the panel (current and voltage) were measured with the aid of a multimeter and the solar illuminance was measured with a Digital Illuminance Meter (model: DT-1309).

RESULT AND ANALYSIS

There are so many weather parameters. The major or basic ones are: air temperature, air pressure, relative humidity and wind [11] [12]. The following are the results from the comparison between solar Illuminance (or intensity) and the outputs of the solar panel within the tropical weather parameters' ranges of 77 ^oF – 90 ^oF (air temperature), 30 inHg – 29.85 inHg (air pressure), 66 % and 89 % (relative humidity) and 5 mph – 10 mph (Wind speed). The wind was running mainly in the WSW direction. Measurements were taken in the time course of daylight, on three (3) different days to reach a rational decision. Fig. 1 shows solar Illuminance (or intensity) against solar panel Outputs (Day 1). Fig. 2 shows solar illuminance (or intensity) against Solar panel Outputs (Day 2) and fig. 3 shows solar Illuminance (or intensity) against solar panel Outputs (Day 3).

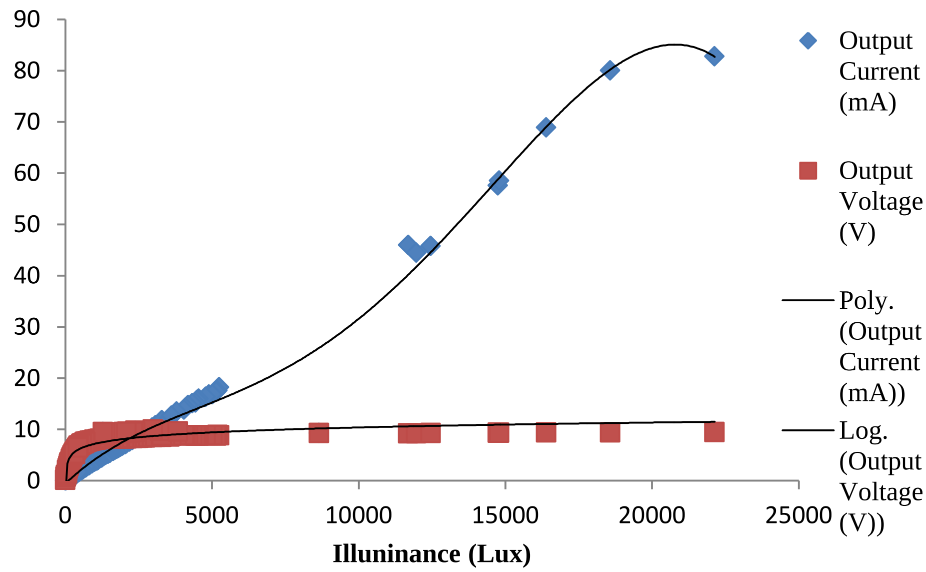


(a)

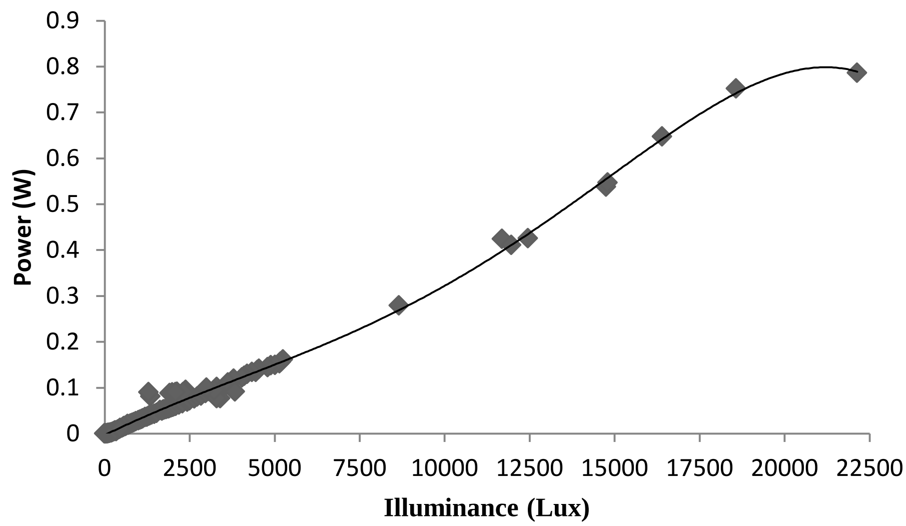


(b)

Fig. 1: Solar illuminance (or intensity) against Solar panel Outputs (Day 1)

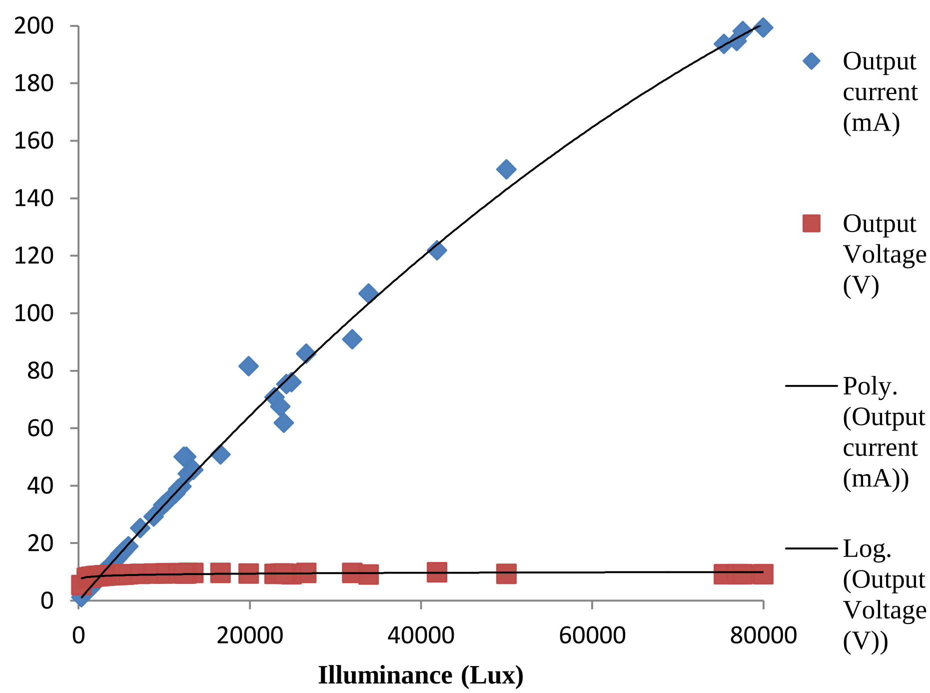


(a)

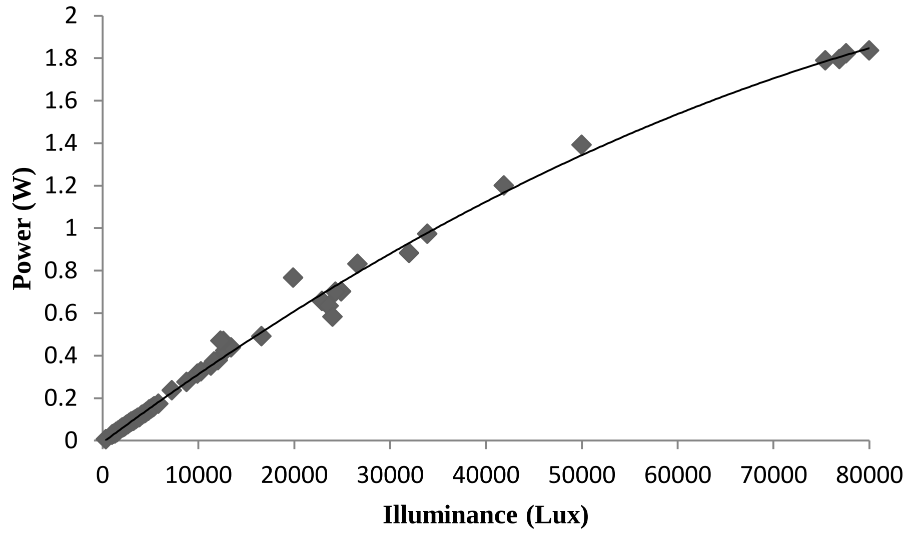


(b)

Fig. 2: Solar illuminance (or intensity) against Solar panel Outputs (Day 2)



(a)



(b)

Fig. 3: Solar illuminance (or intensity) against Solar panel Outputs (Day 3)

In fig. 1 observe that the output voltage rises rapidly to a maximum value and remains steady throughout, despite increase in solar illuminance (or intensity). While the current rises steadily to a maximum against solar illuminance (or intensity). The voltage curve is logarithmic while the current curve is polynomial.

Also fig. 1, the power rises steadily to a maximum against solar illuminance (or intensity). The power output curve is a twin of that of the current in regard to form. In other words, with increasing solar illuminance (or intensity), the current output is directly proportional to the power output, regardless of the voltage output. The maximum solar illuminance in fig. 1 is 24 Klux and at this value, there was still room for increment of current output against increasing illuminance, since the curve at the tail end is still steep.

In fig. 2, the voltage output rises rapidly to a maximum value and ceases. Afterwards, it maintains a flat response curve, despite increase in solar illuminance (or intensity). However, the current output rises gradually, but retarding in steepness to a maximum value, thereafter, increament was nearly negligible and the output current begins to drop with further increment in solar illuminance (or intensity). The drop is as a result of random orientation and collision of the excess electrons extracted from the solar cell atoms, causing an opposition to free flow. This occurs at an illuminance (or intensity) of 25.5 Klux.

Also in fig. 2, the current output response is polynomial and that of the voltage is logarithim like the latter fig. More so, the power output curve parallels the output current curve. Hence, the output current is positively proportional to the power output curve.

In fig. 3, there is a steady rise in the output current at the onset and gradual decay in the steepness towards the tail end. This is due to the approach of avalanche of extracted electrons from the solar cell atoms, resulting in a bit by bit disorientation of the electron flow. A point of fact is that current is a rhythmic but not randomize flow of electrons. In the event of an overwhelming rain of light particle, a flood of electrons is produced by the solar cells resulting in a disorientation and collision.

Also, in fig. 3, the power output response curve is an image of the current output curve in regard to form. This indicates that the current output is directly proportional to the power output. Similar to fig. 1 and fig. 2; the current output curve is polynomial and that of the voltage is logarithmic.

In the three (3) figs., the power output rating can be enhanced at high solar illuminance (or intensity), despite the solar panel rating (1.5 W, 12 V). This is as a result of increasing current due to higher level of illuminance (or intensity).

CONCLUSION AND RECOMMENDATIONS

This paper has shown that, solar cell output efficiency is highly enhanced by an increase in solar illuminance (or intensity). The current rises steadily with increase in solar illuminance or intensity. However, the rise rate reduces at a point with further increase in illuminance, when the raining light excessively extract and excite electrons (or holes), gradually resulting in a randomized flow, rather than the regular flow. The voltage output rises sharply with increasing illuminance or intensity, but at a certain point attains the maximum level. Afterwards, the rate of change of the voltage with increasing illuminance or intensity becomes insignificant. The response curve at this point becomes steady. The current output of solar cells is polynomial while that of the voltage is logarithmic. The power output of the solar cell is directly proportional to the output current with change in illuminance, regardless of that of the voltage under similar atmospheric conditions and within the limit of the photovoltaic cell rating. The power output response curve takes the form of the current curve. Hence under similar weather conditions, provided that the capacity of a photovoltaic cell is not exceeded – $P = KIL^2$: where P is the power (Watt), I is the current (A), L is illuminance (Lux) and K is the loss or gain power factor depending on the photovoltaic cell.

Since solar illuminance (or intensity) has a high positive effect on the solar cells, a good converging less to focus solar radiations on the photovoltaic panel will really enhance the efficiency of the output, most especially in regions of low sunlight.

Also, since the current is generated as a result of photoelectric effect. It is possible for higher energetic particles above the ultraviolent particles to extract and excite more electron or current than solar radiation (mainly ultraviolent particles) and improve output. This may be recommended for the Polar Regions. Gamma or X-ray particles may be incident on the photovoltaic panel.

REFERENCES:

[1] Luminosity (2016.). Oxford Dictionaries. Oxford: Oxford University Press. Retrieved 30 May, 2016, From Http://Www.Oxforddictionaries.Com/Definition/English/Luminosity.

[2] Illuminance (2016.). Oxford Dictionaries. Oxford: Oxford University Press. Retrieved 30 May, 2016, From Http://Www.Oxforddictionaries.Com/Definition/English/Illuminance.

[3] Illuminance (2016). In Wikipedia: The Free Encyclopaedia. Retrieved 30 May, 2016, From Https://En.Wikipedia.Org/Wiki/Illuminance.

[4] Taylor F. E. A. (N.D.). Illumination Fundamentals. Retrieved 30 May, 2016, From Https://Optics.Synopsys.Com/Lighttools/Pdfs/Illuminationfund.Pdf.

[5] Gordo E., Khalaf N., Strangeowl T. (2015). Factors Affecting Solar Production Efficiency. New Mexico Supercomputing Challenge, Final Report By Team 88: Miyamura High School.

[6] Amajama J. (2016). A Bizarre Design And Engineering Physics Of Small/Micro And Pico/Family Hydro-Electric Power Plants/Farms. *Journal Of Scientific And Engineering Research*. 3(2). In Press.

[7] Bunea G, Wilson K, Meydbray Y, Campbell M, Ceuster D. Low Light Performance of Mono-Crystalline Silicon Solar Cells. In: 4th World Conference on Photovoltaic Energy Conference. Waikoloa, Hi; 2006. Pp. 1312–1314. Available From: Http://Ieeexplore.Ieee.Org/Xpls/Abs_All.Jsp?Arnumber=4059885&Amp;Tag=1.

[8] Solar Cells: Solar Cell Model & What affects Solar Cell performance & Efficiency (2014). In Solar Love. Retrieved 10 My, 2016, from http://solarlove.org/solar -cell-and-its-characteristics/.

[9] Science Buddies Staff (2016). How does Solar Cells output vary with incident light intensity?. Retrieved July 11, 2016 from http://www.sciencebuddies.org/science-fairprojects/project_ideas/energy_p014.shtml.

[10] Narendra Kumar M., Saini H.S., Anjaneyulu K. S. R. &. Singh K. (2014). Solar Power Analysis Based on Light Intensity. *The International Journal of Engineering and Science*, 2319 –1805.

[11] Weather and Atmosphere (n.d.). In Fundamentals of Environmental Measurements. Retrieved 10 May, 2016 from http://www.fondriest.com/environmental_measurements/parameter/weather/.

[12] Hocking W. K. (2000). *The Instruments Of Meteorology*. Retrieved 10 May, 2016, From Http://Www.Physics.Uwo.Ca/~Whocking/P103/Instrum.Html.

.