

Determination of the Actual Amount of Insolation Absorbed by a Photovoltaic Panel (125w)

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Abstract: The determination of the ability of the Photovoltaic cell in absorbing radiation was performed, taking into cognizance the fact that photovoltaic panels have the ability to harness solar energy incident on it in the form of radiation. It utilized the hourly production of open circuit voltage for a 125W module Photovoltaic panel made of silicon material. The solar panel was exposed to the open atmosphere from sunrise to sunset, precisely from 5.00am to 7.00am, with no obstruction from heights, high rise buildings and tall trees including towers. The photovoltaic panel was brought to ambient temperature and results were taken in clear sky weather condition in the neighborhood of ± 10 minutes to the hour mark. The voltage output was recorded with the aid of a digital multimeter and a Power model was used to determine the actual amount of radiation available and a plot of voltage V hours and Watt V hour when done, showed the same pattern as that of Adnot, Haurwitz and Alboteani et al. results. The hourly variation of voltage graph when assessed, showed an ascendancy as the hour increased to a maximum of 20.65Volts at mid day and then a decrease to 0 volts at twilight (7.00pm) on the 11th day of November, 2017. The same ascendancy and decrease patterns were also displayed by the hourly variation of absorbed power. Thus, photovoltaic panel output varies with the sun hours like solar radiation varies with the sun hours, when results are obtained are obtained under stated conditions. Hence, results stands validated.

Keywords: Photovoltaic Plate, Solar Radiation, Sun Hour, Clear Sky Weather, Voltage Output and Power

1. Introduction

The energy radiated from the solar system releases Extraterrestrial radiation that reaches and impinges on Photovoltaic cells as terrestrial radiation. The most important characteristic of the Photovoltaic panel is its conversion efficiency, which expresses the amount of solar radiation available in the incident radiation [1]. Empirical calculation of Extraterrestrial radiation have been done in the works of [2-6] etc.

Alboteanu et al, placed global radiation as

$$G_g = \left(\frac{24}{\pi}\right) \times s(0.33\cos(\frac{2\pi n}{365})\cos\theta\sin\alpha_s + \omega_s\sin\theta\sin\alpha_s)$$

Where S = Solar constant

G_g = Global radiation

n = no. days of the year

θ = latitude

ω_s = Solar angle

δ = Declination angle

His work also showed the calculation of Terrestrial irradiation. The extract identified empirical models which calculated the amount of solar radiation present with respect to the time of the day and had the highest insolation at noon day for clear sky conditions. These models were

The Adnot model: $G_g = 953.9(\sin\alpha_s)^{1.5}$ w/s

Haurwitz model: $G_g = 1.098e^{(0.057/\sin\alpha_s)}\sin\alpha_s$ w/m²

Kasten model = $G_g = 910(\sin\alpha_s) - 30$ w/m²

Empirical EIM by Paulescu and Schlet

Where α_s = angle between sun and horizontal $\sin\alpha_s$

The business of this work is to calculate the actual amount of radiation absorbed by a 125W module photovoltaic panel. This actual amount of absorbed radiation is calculated using a power model and the result tabulated in a table of open

circuit voltages. This is in line with the work of [7], as it clearly stated that most meteorological stations did not have solar radiation data for hourly estimation, which is a necessary parameter for performance evaluation of solar energy systems if accurately done. It is of the essence to note that precise measurement of hourly and daily solar radiation is best done by automated materials[8].

The work further experimentally determined the hourly instantaneous open circuit voltage from dawn till twilight and used it to show the behavioral pattern of available radiation.

2. Materials and Methods

2.1. Experimental Set up

The following materials were utilized:

- 125W Photovoltaic panel
- Clear sky weather condition
- Multimeter

d) Cooling water at 25°C

Procedure

- Obtain a horizontal platform in an open space, without any aerial obstruction.
- Record hourly readings of open circuit voltage (V_{ocv}) from 5:00am to 7:00pm on 18th November, 2017.
- Ensure that photovoltaic panel is at least at ambient temperature before recording V_{ocv} .
- Plotgraph with V_{ocv} V Hours
- Plot graphs of actual power V hour and absorbed power V hour.

2.2. Power Model

The power model is defined as: Power (P)

$$p = 0.92R_f P_i \delta$$

Where R_f = reflectivity of aluminum

P_i = standard inputs (power)

δ = band absorbance of visible light

Table 1. Table of Voltages.

S/No	Nominal Power provided (W)	Actual Power input ($0.92 R_f P_i$) (W)	Power Absorbed ($K \cdot P_i$) (W)	$V_{ocv-125}$
01	60w	55.2	25.39	13.3
02	70	64.4	29.62	
03	80	73.6	33.86	
04	90	82.8	38.09	
05	100	92	42.82	
06	110	101.2	46.55	
07	120	110.4	50.78	17.1
08	130	119.6	55.02	17.4
09	140	128.8	59.24	17.7
10	150	138	63.48	18.0
11	160	147.2	67.7	18.3
12	170	156.4	71.9	18.6
13	180	165.6	76.18	18.9
14	190	174.8	80.41	19.2
15	200	184	84.64	19.45
16	210	190.8	88.87	19.7
17	220	202.4	9.0	20.0
18	230	211.6	97.34	20.2
19	240	220.8	101.57	20.3
20	250	230	105.8	20.4
21	260	239.2	110.03	20.48
22	270	248.4	114.26	20.52

The above table was prepared for PVC module 125W, $V_{max} = 21.3v$ which gave actual $V_{max} = 20.6v$. for Port Harcourt environment. [9]

3. Results

Table 2. Hour Table.

	Time	Hour	$V_{ocv}(v)$	Absorbed Power(w)	Actual $P_i(w)$
1	5am	5	0	0	0
2	6am	6	3.38	6.45	14.08
3	7am	7	17.44	55.02	119.6
4	8am	8	19.0	76.18	165.6
5	9am	9	20.0	93.1	202.4
6	10am	10	20.4	105.8	230
7	11am	11	20.5	114	248
8	12pm	12	20.65	135	294
9	1pm	13	20.5	114	248
10	2pm	14	20.3	101.57	220.8
11	3pm	15	20.0	93.1	202.4

	Time	Hour	V _{ocv} (v)	Absorbed Power(w)	Actual P _i (w)
12	4pm	16	19.0	76.18	165.9
13	5pm	17	17.45	55.02	119.6
14	6pm	18	3.4	6.45	14.08
15	7pm	19	0	0	0

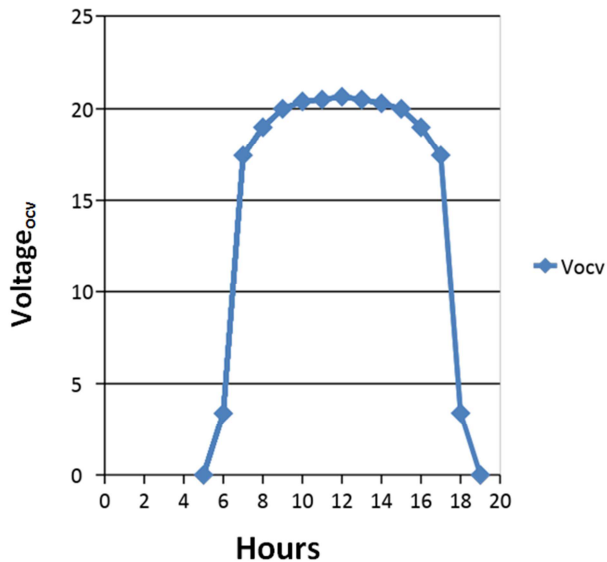


Figure 1. Hourly Variation of Voltage.

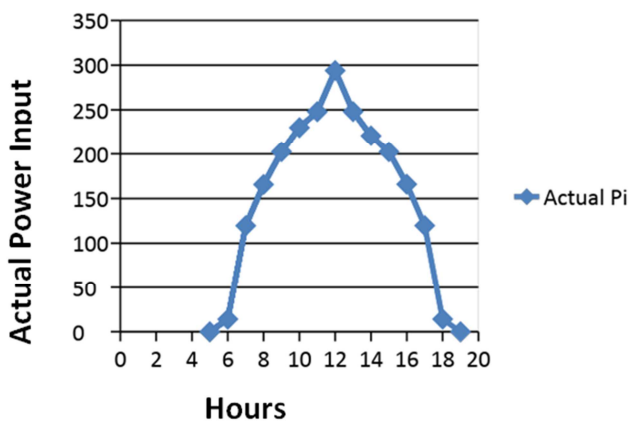


Figure 2. Hourly Variation of Actual Power Input.

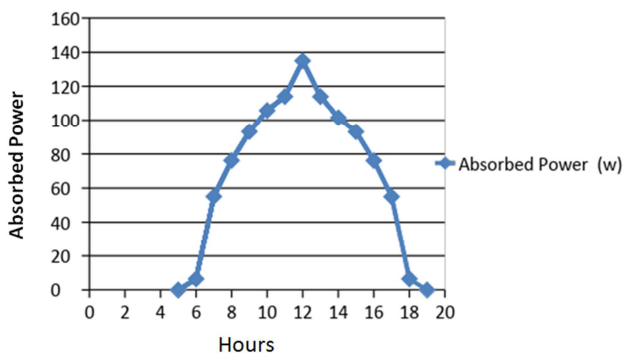


Figure 3. Hourly Variation with Absorbed Power by Photovoltaic Panel (125w).

3.1. Calculation (Interpolation)

For V_{ocv} @ 3.38,

Absorbed P_i (x) is Actual P_i(x) is

$$\frac{3.38 - 0}{13.3 - 0} = \frac{x - 0}{25.39 - 0}$$

$$x = 6.45 \text{ w}$$

$$\frac{3.38 - 0}{13.3 - 0} = \frac{x - 0}{55.2 - 0}$$

$$x = 14.08 \text{ w}$$

3.2. Discussion

The table of voltages as introduced is used to denote and recognize the actual power absorbed by the Photovoltaic panel and the minimum amount of radiation capable of generating the corresponding open circuit voltage.

Figures 1 and 2 were used to present the hourly increase in the voltage and corresponding power respectively. In both figures, there is an increase from a value of zero at 5:00, to maximum of 20.6 V at 12.00 pm for figure 1 and a maximum of 294 W for figure 2. Result however showed a gradual decrease at the other hours, corresponding to the variation from noonday for the hours before noon. i.e. 11am = 1pm, 10am = 2pm etc. at clear sky weather condition. Figure 3, also replicated the same trend as the photovoltaic panel absorbed power according to the hourly radiation present but with a peak value of 135 W.

Thus, photovoltaic panel output varies with the sun hours like solar radiation varies with the sun hours. The graph from a plot of V_{ocv} Versus hours is similar to graph from power V hours in [2] and also similar to figure 4. Figure 4 represents a standard result got from standard models and it compares favorably with results obtained in this work.

4. Conclusions

The actual amount of solar radiation that is incident on photovoltaic panels as found from the work shows that extraterrestrial radiation value is greatly reduced as a result of weather and climatic conditions. It was however ascertained that:

- The result obtained showed that photovoltaic output (instantaneous) in clear sky weather varies as solar output, with the time of the day.
- For clear sky weather condition, solar radiation values are maximum at noonday (the solar noon) and minimum values occurred during the dawn and night periods.
- The power obtained from the table of voltages, generated from the power model, was used to estimate the amount of the hourly solar radiation that is present in Port Harcourt.

d) Photovoltaic(PV)panel output can be used to estimate both the absorbed power by the PV and incident solar power, if the table of voltages for particular module is known.

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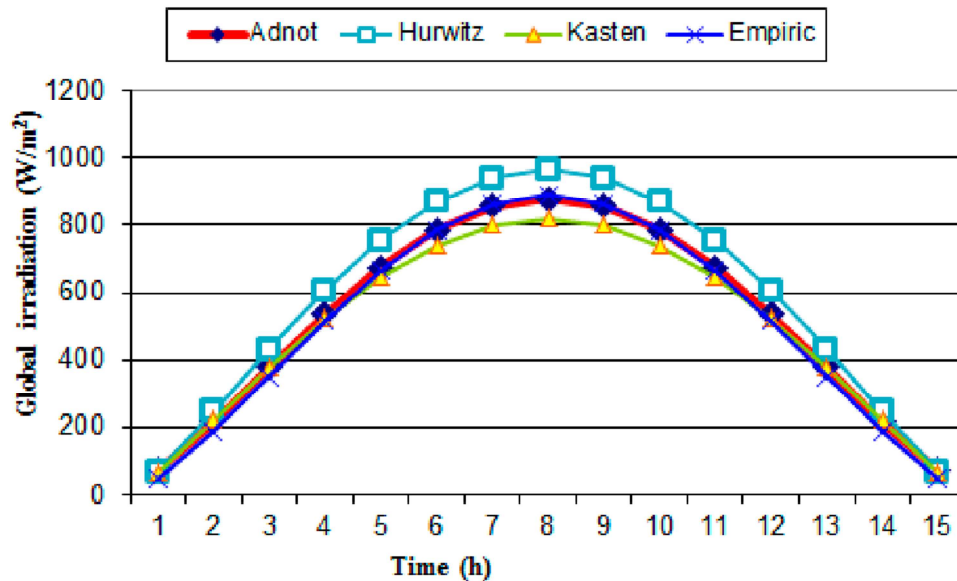


Figure 4. Hourly Variation of Solar Radiation [2].

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