Performance Parameters Evaluation of Amorphous Photovoltaic Modules in a Semi-Arid Climate Conditions: the case of Ekiadolor Community, Nigeria.

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Abstract:

The effects of temperature and radiation intensity on the performance parameters of amorphous silicon (a–Si) photovoltaic module have been investigated. An outdoor experimental setup was installed to carry out a series of I–VII parameter measurements under different irradiance and temperature conditions of the module. The module parameters extracted from I–VII measurements were employed to calculate the module performance parameters, i.e. open circuit voltage $V_{oc,}$ Maximum power P_{max}, fill factor FF and Module efficiency η at different temperature range and irradiation intensity. Results obtained indicate that the module parameters have significant effect on module performance. Also, the behaviour of V_{oe}, I_{sc} and $P_{max}$are completely different at higher irradiance and temperature.

Keywords: Amorphous, irradiance, fill factor, photovoltaic, efficiency.

Nomenclature

AM: air mass
Aa: active area of module (m^2)
a-Si: amorphous silicon module
E: solar irradiance (W/m^2)
STC: standard test condition
δ: angle of tilt with horizontal
V_{oc}: Open circuit voltage (V)
E_H: Solar irradiance at horizontal surface (W/m^2)
η: Module efficiency
PV: photovoltaic
I_{max}: Maximum Current (A)
I_{sc}: Short Circuit current (A)
POA: Plane of array
P_{max}: Maximum power
E_D: direct solar irradiance (W/m^2)
V_{max}: Maximum Voltage (V)

1.0 Introduction

Photovoltaic technology clearly offers tremendous environmental benefits, requiring no fuel and producing no emissions or other waste beyond that inherent in the manufacturing process. The adaptation of thin film solar modules in many applications is growing in the last few decades due to their low cost and manufacturing technology. Amorphous silicon (a–Si) module is considered as one of the most promising technology for this area. So, the detailed outdoor behaviour of these modules is required under different environmental conditions.

In a–Si module, the diffusion length of the charge carriers is much shorter than crystalline silicon modules, solar cell structure is based on the transport of minority carriers in the quasi neutral region of the Pn junction, which is not the case for a–Si Due to the very short diffusion length the photo-generated carriers would virtually all recombine in the doped layers of a–Si before reaching the depletion region on the Pn junction so, a different technique namely intrinsic layer is adopted to manufacture the a–Si solar cells. The photo-generated carriers move towards the doped layers (electrons toward the n–type and holes toward the P–type) and are collected by electrodes. The dominant transport mechanism of photo-generated carriers is drift in the internal electric field and therefore a–Si solar cells are often called drift devices [1].

The outdoor performance of a–Si modules under different solar irradiance and device temperature and or spectral irradiance is vital for selecting the proper solar module for certain location and specific application. The information given by the manufactures of a PV module is based on standard test condition (STC), irradiance 1000 W/m^2 module temperature 25^{oc} and air mass (AM 1.5) and electrical properties of a PV device comprises of Seven parameters: open circuit voltage, V_{oe}, short current, I_{sc}, maximum voltage, V_{max}, maximum current efficiencyη and fill factor, FF. these parameters measured at standard test condition. (STC) are supplied by the manufacturer. The results may not agreed with the operating condition due to variations of environmental parameters [2]. The module temperature affects the characteristic parameters of the module. It is well researched fact that at high temperature, output of a PV module decreases [3]. Therefore, a cooling mechanism is required at high solar insulation [4]. The PV modules exposed to sunlight in actual operating condition for a long time do not maintained their initial operating conditions. Modules undergo some degradation and hence module performance decreases [5], [6].

Also, 32% reduction in performance of PV module in USA during 8 – mouths due to the dust accumulation was reported by [7]. While the effect of dust deposition using a test chamber and solar simulator in the lab and found a decrease in module efficiency up to 26% for dust accumulation of 22g/m^2 was investigated by [8].Investigation of the effect of airborne dust and wind speed on the performance of PV modules was carried out by [9]. They found that these factor have a significant effect on the module performance.

In the present work seven parameter of amorphous silicon modules were monitored at different weather conditions for the period May 2016 to August, 2016.

2.0 Materials and Methods

In this study, commercially available amorphous silicon module was used in carryout the analysis. Table 1shows the specifications and characteristic parameters of the module used in this research. Rated values given by the manufacturer of the PV module at STC and actual values are measured at outdoor conditions.

Table 1: Module specification and characteristic parameters

Dimension	A – Si
Module dimension (mmxmm)	1250x640
Cell dimension (mmxmm)	1220x610
Number of cells (in series)	1
Cell area (m^2)	0.7442
Maximum Power, P_{max} (w)	100
Maximum Current, I_{max} (A)	2.69
Maximum Voltage, V_{oc} (V)	45
Short Circuit current, I_{sc}	3.34
Open Circuit Voltage, V_{oc}	59.2

2.1 Experimental Setup and Approach

In order to carry out the performance parameter analysis for the amorphous silicon module, the experiment was performed at the front of Physic Department of College of Education, Ekiadolor, Benin in the Southern Ekiadolor Community (Latitude 6.59^{o}N, Longitude 5.50^{o}E) as shown in Fig 1. The place of the solar module was chosen such that a shadow will not be cast into solar module at any time during the evaluation period. Measurement were taken hourly from 8am to 5pm. The module under study was mounted on the south facing rack at fixed tilted angle of 15^0 the site during May through August, 2016. The plane of array (POA) global solar irradiance was measured using a pyranometer TBQ-2 (sensitivity 11.346-V/Wm^2). The a–Si module was connected to two digital multimeter (Fluke 179, True RSM, accuracy: ±1% for

DC current and ± 0.09% for DC Volt) for the measurement of Voltage and current. A high power muttiturn variable resistance (100W) was connected in series in the circuit to vary the output of the module from zero to maximum. A standard resistance of thermometer detector (RTD – PT100) was used to monitor the surrounding ambient temperature to guarantee high accuracy for critical temperature. The maximum power, P_{max}, fill factor, FF, module conversion efficiency, η and performance, ratio (PR) were calculated to understand the behaviour of the solar module. Using the following equations:

Maximum Power (P_{max}) = $V_{max} \text{ x } I_{max}$ (2.1)

Fill Factor (FF) = $(V_{max} \text{ x } I_{max})/(V_{oc} \text{ x } I_{sc})$ (2.2)

Normalized Power output efficiency (ϱ_p) = (P_{men}/P_{max})STCx100 (2.3)

Module efficiency (ϱ_m) = $(P_{mea}/(E_x A/A_c))$x100 (2.4)

Performance ratio (P_R) = P_{mae}/P_{max}(STC)/E x100 (2.5)

Direct sola irradiance (E_D) = $E_H/\text{Cos}(\delta)$ (2.6)

To determine quantitatively the effect of temperature on different electrical parameters, we used the following question to find out the effects of working temperature (T_w) on these parameters with references to their values at STC.

$(V_{oc})T_w = (V_{oc})\text{ STC} + \alpha(T_w - 25^{oC})$ (2.7)

$(I_{sc})T_w = (I_{sc})\text{ STC} + ß(T_w - 25^{oC})$ (2.8)

$(P_{max})T_w = (P_{max})\text{ STC} + ÿ(T_w - 25^{oC})$ (2.9)

$(\varrho_m)T_w = (\varrho_m)\text{ STC} + \partial(T_w - 25^{oC})$ (2.10)

$(FF)T_w = (FF)\text{ STC} + Ɛ(T_w - 25^{oC})$ (2.11)

Where:

T_w = working temperature.

$\alpha = \frac{dVoc}{dT}$ (V^oC^{-1})

$ß = \frac{dIsc}{dT}$ (A^{oe})

$ÿ = \frac{dPmax}{dT}$ (W^oC^{-1})

$\partial = \frac{dII}{dT}$ ($\%C^{-1}$)

$Ɛ = \frac{dFF}{dT}$ ($^oC^{-1}$)

Fig 1: Experimental Readings of a-Si module.

2.2 Experimental Data and Parameters analysis

In this section, we studied the effect of temperature change of a–Si PV panel performance. In this phase, the panel was pointed to the sun and temperatures were recorded from 8am to 5pm daily for the period of May, 2015 to August, 2016. Table 2 present experimental average parameters obtained.

Table 2: Average Performance Parameter obtained for the period of May, 2016 to August, 2016.

Time (day)	Temp (^{o}c)	V_{oc} (V)	I_{sc} (A)	V_{max} (V)	Imax (A)	P_{max}	FF	N (%)	E (W/m^2)
8.0	30.00	47.32	2.70	36.44	2.17	79.07	0.62	11	243
9.0	34.00	56.73	3.20	43.12	2.58	111.25	0.61	15	288
10.0	34.00	56.73	3.20	43.12	2.58	111.25	0.61	15	350
11.0	40.00	69.07	3.90	52.50	3.14	164.85	0.61	22	363
12.0	43.00	73.55	4.15	55.88	3.14	186.08	0.61	25	580
1.0	47.00	78.40	4.42	59.64	3.33	210.53	0.61	28	873
2.0	47.00	78.40	4.42	59.64	3.53	200.53	0.61	28	720
3.0	44.00	74.87	4.22	56.50	3.41	193.96	0.61	28	690
4.0	40.00	69.07	3.90	52.50	3.41	164.85	0.61	26	600
5.0	21.00	59.20	3.34	45.00	2.69	121.05	0.61	22	418

3.0 Results and Discussion.

During the study, the variation in daily average irradiance and temperature are shown in table 2. The irradiance was measured in plane with the PV module. The average, maximum and minimum irradiance of experiment in all days were 512 W/m^2, 873W/m^2 and 243W/m^2respectively. The average irradiance was maximum at 1.00pm correspond to the peak out power of the solar module. The temperature of the module stays above the ambient temperature unless at 5pm and increase with increase in irradiance the increase in module temperature with irradiance is due to the production of heat during the photovoltaic reaction. In the evening at 5pm, the module temperature reaches below the ambient temperature. This is due to the fact of sudden decrease in irradiance which significantly slows down the photovoltaic process and hence decreases the module temperature. It is observed that the normalized output efficiency increases steadily with increase in irradiance. The maximum power output efficiency was at 1pm corresponding to maximum irradiance. At 8am, the average power output efficiency of the amorphous silicon is 11% at 1pm it is 28% which shows that a–Si performs better in high light condition at Ekiadolor community. It was found that there is a linear increase in photo-generated current with increased photo flux as irradiance levels increase, resulting in an increase in current with increased irradiance. Also, it was observed that there is great variation in power produced from day to day due to the fluctuations in daily irradiation and other meteorological parameters such as temperature.

4.0 Conclusion

The commercially available amorphous silicon PV module has been tested at outdoor conditions of Ekiadolor, Nigeria during the Mouth of May, 2016 to August, 2016. A custom made setup was used to determine the characteristic parameters of PV module under study. The results have shown that output power of module varies linearly with irradiance and a–Si module has shown 28% average normalized output efficiency at 1pm. Ekiadolor has favourable climate for the implementation of amorphous silicon technology with long sunshine hours and high isolation level. Due to the capability of having high fill factor (FF) as shown in Table 2, a–Si module is found to be suitable in Ekiadolor and its surrounding regions.

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