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THEME:
SUSTAINABLE ENERGY IN CHANGING CLIMATE: THE ROLE OF SCIENCE AND TECHNOLOGY

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Analysis of Degradation of Mono-Crystalline Photo Voltaic Modules after Four (4) Years of Outdoor Exposure in Minna, North-Central Nigerial

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Abstract

The understanding of degradation modes and mechanism is very important in order to ensure the lifetime of a Photovoltaic (PV) modules and to predict the total lifespan. In the present study, degradation analysis of mono-crystalline silicon PV modules under test and meteorological sensors installed on a metal support Mask at the Experimental Garden near Physics Department of Federal University OF Technology, Minna, has been carried out after 4 years of outdoor operation in a composite climate of Central Nigeria. A comprehensive analysis has been carried out on Mono-crystalline PV Module rated 10W using CR1000 software-based Data Acquisition System (DAS) through visual inspection, Open-Circuit Voltage (Voc), Short-Circuit Current (Isc),I-V characteristic. The data monitoring was from 09:00am to 18:00 pm hours each day continuously for four years, from December 2014 to November 2018. Annual yearly average of the performance variables were calculated to have the full knowledge of the degradation rate and the lifespan of the module. It was observed that Open-Circuit Voltage (V oc), Short-circuit Current (I sc), Power (W), Maximum Voltage (Vmax), Maximum Current (I Max) and Power Maximum (P Max) has average yearly degradation of 1.07V; 0.007A, P(W), 0.08W, 1.7V, 0.017A and 0.14W for the four years

1. Introduction

It is importance to know that the sun is the nearest star and therefore the source of all renewable energy on earth which provide sustenance for both plants and animals. Photovoltaic module in the local environment will establish performance comparison between the locally available modules types. The result of this investigations will assist the designers, scientists and Energy Research centers to get first-hand information on the modules performance in the local environment before they proceeds on design and installation for power supply. Indeed, solar energy is used for industry, Communities as well as individual needs. Over the past decade, the photovoltaic (PV) market has experienced unprecedented growth and beside these, photovoltaic market has reached a cumulative installed capacity of roughly 40 GW world-wide, with an annual added capacity of 16.6 GW (EPIA, 2011).

However, there is little information on PV modules degradation modules in terms of frequency, speed of evolution and degree of impact on module lifetime and reliability. Research on photovoltaic modules is rather focused on the race to develop new technologies without sufficient experience feedback on already operational technologies (Laronde, 2009; Tiwari and Dubey, 2010). For economy development in a society, the rate at which the demands for electricity will be increases, let us consider the present situation, primary energy account for 40% of the global energy used for power generation, and solar or renewable energy only account for 3.6% (Nasiro,S:Rev.2018,95 194-202).It is importance to know that the sun is the nearest star and therefore the source of all renewable energy on earth which provide sustenance for both plants and animals.(Joel. E 2016).The investigating of the performance of mono-crystalline photovoltaic module in the local environment will establish performance comparison between the locally available modules types. The result of this investigations will assist the designers, scientists and Energy Research centers to get first-hand information on the modules performance in the local environment before they proceeds on design and installation for power supply.

2. Material and Method

2.1 Method of Data acquisition.

The research was carried out at the premises of Bosso Campus of Federal University of Technology, Minna, Niger State. The studied of the specific effect of ambient weather parameters which includes: Temperature, Solar irradiance, wind speed and relative humidity on performance of mono-crystalline photovoltaic module ,analyzing the observed data and convert to compare with the producer specification as the result will indicate any variance resulted from the meteorological effects indicate the degradation.

The research process involved two process which include Date acquisition by continuous monitoring and Date analysis.

3.1 Monitoring State

The performance response of the mono-crystalline PV modules to ambient weather parameters; solar irradiance, temperature, wind speed and relative humidity, was monitored in Minna environment, using CR1000 software-based data logging system with computer interface. The PV modules under test, and meteorological sensors, were installed on support structure at the same test plane, at about three metres of height, so as to ensure adequate exposure to insolation and enough wind speed, since wind speed is proportional to height. The elevation equally ensures that the system is free from any shading from shrubs and also protected from damage or interference by intruders. Also, the whole experimental set up was secured in an area of about four metres in diameter. The modules were tilted at approximately 10o (since Minna is on latitude 09o37' N) to horizontal and south facing to ensure maximum insolation (Ezenwora .J, 2016; Scheller *at el.*, 1991; and Ugwuoke *at al.*, 2006). The data monitoring was from 8.00 am to 6.00 pm local time, each day continuously for a period of four year, starting from December 2014 to November 2018, so as to cover the two distinct and well defined climate seasons of the area. The experiment was carried out at Experimental Guarding at Bosso

Campus of Federal University of Techology, Minna (latitude 09o37' N, longitude 06o32' E and 249 meter above sea level). The sensors were connected directly to the CR1000 Campbell Scientific data logger, while the modules are connected to the logger via electronic loads. The logger was programmed to scan the load current from 0 to 1 A at intervals of 50 mA every 5 minutes, and average values of short-circuit current, Isc, open-circuit voltage, Voc, current at maximum power, Imax, voltage at maximum power, Vmax, power and maximum power obtained from the modules together with the ambient parameters are recorded and logged. Data download at the data acquisition site was performed every 7 days to ensure effective and close monitoring of the DAS. At the end of each month and where necessary, hourly, daily and monthly averages of each of the parameters - solar irradiance, solar insolation, wind speed, ambient and module temperatures, and the output response variables (open-circuit voltage, V_{oc}, short-circuit current, I_{sc}, voltage at maximum power, Vmax, current at maximum power, Imax, efficiency, Eff and fill factor, FF) of the photovoltaic modules were obtained. The global solar radiation was monitored using Li-200SA M200 Pyra-nometer, manufactured by LI-COR Inc. USA, with calibration of 94.62 microamperes per 1000 W/m2. The ambient temperature and relative humidity were monitored using HC2S3-L Rotronic Hy-groClip2 Temperature/Relative

Humidity probe, manufactured in Switzerland. Wind speed was monitored using 03002-L RM Young Wind Sentry Set. And module temperature was monitored using 110PV-L Surface-Mount Temperature probe. All sensors were installed in the CR1000 Campbell Scientific data logger with measurement and control module as show below.

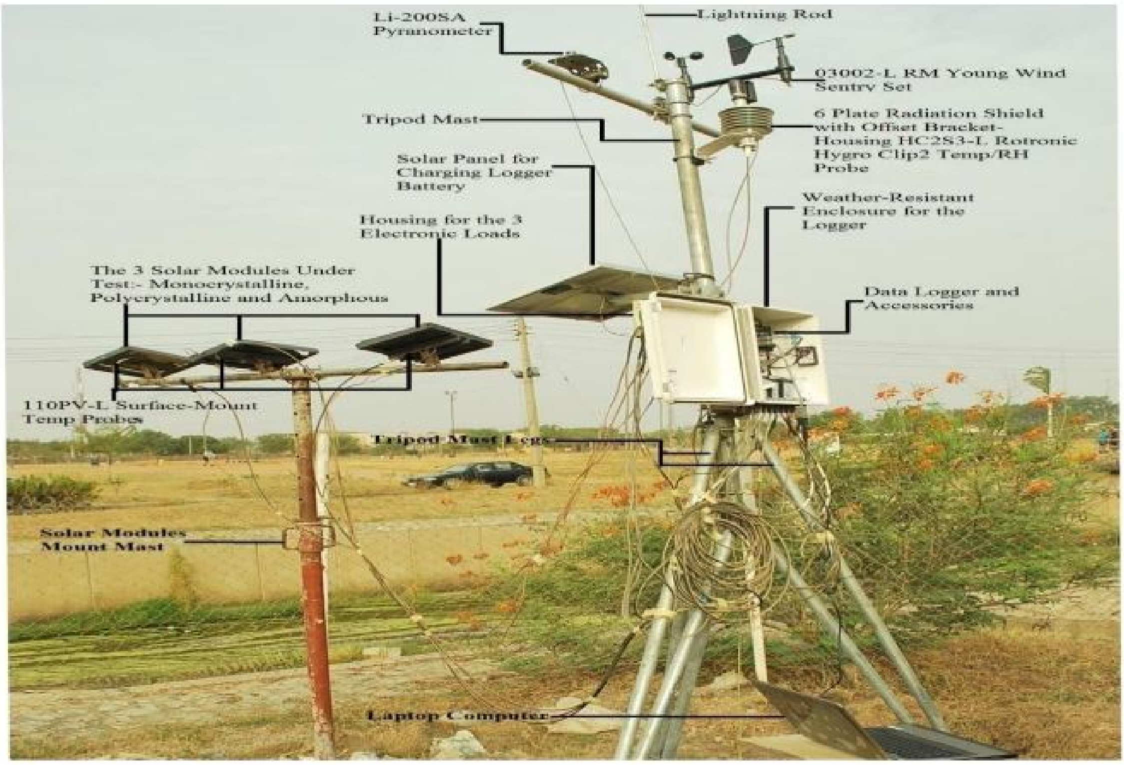

Plate 1:The Experimental set Up (Near Physics Department, FUT Minna)

2.2. Method Data Analysis

Analysis of the yearly degradation rate of the mono-crystalline module by solar irradiance was investigated in terms of open circuit voltage (Voc),Short-circuit current (Isc) Voltage at Maximum power (Pmax),current at maximum power(Imax),Efficiency(Eff) and Fill factor(FF).All the parameters and module performance Ratio (MPR) were evaluated using the following expressions(Ugwuoke,2005;Ezenwora, 2016)

Fill factor (FF) = $I_{max}V_{Max}/I_{SC}\ Voc$ (1)

Efficiency (Eff) = $^{I_{Max}V_{max}}/_{P_{in}} = I_{sc}VocFF/P_{in} = ^{I_{sc}V_{OC}}/_{AE_e}$ (2)

Module Performance Ration (MPR) = Effective Efficiency/Efficiency at STC (3)

The maximum power (P max) which is the operating point of the module, was recorded by the logger it was corresponds to the large area under the I-v curve .The current and voltage at this point are Imax and Vmax respectively.

3. Results and Discussions

T (Years)	WS (m/s)	T_a (^0C)	RH (%)	T_{mod} (^0C)	H_g (W/m^2)	V_{sc} (v)	I_{sc} (A)	P (W)	V_{max} (V)	I_{max} (A)	P max	FF	Eff (%)
YEAR 1 (2015)	1.65	25.4	48.3	38.9	477	4.62	0.038	0.342	4.62	0.095	0.543	2.477	0.03
YEAR 2 (2016)	1.57	31.4	49.7	39.3	520	3.91	0.039	0.282	3.91	0.087	0.439	2.235	0.02
YEAR 3 (2017)	1.34	32.3	47.1	40.8	502	4.02	0.045	0.274	4.03	0.094	0.455	2.112	0.03
YEAR 4 (2018)	1.03	32.7	53.1	41.0	485	1.64	0.034	0.094	1.64	0.057	0.154	1.701	0.01
AVERAGE	1.40	30.5	49.6	40.0	496	3.55	0.039	0.248	3.55	0.083	0.398	2.131	0.02

Table 1: Annual Average f Ambient Parameters and Performance Variables For the Mono-Crystalline Module.

Figure 1: Yearly Variation of Short Circuit Current and Open-Circuit Voltage.

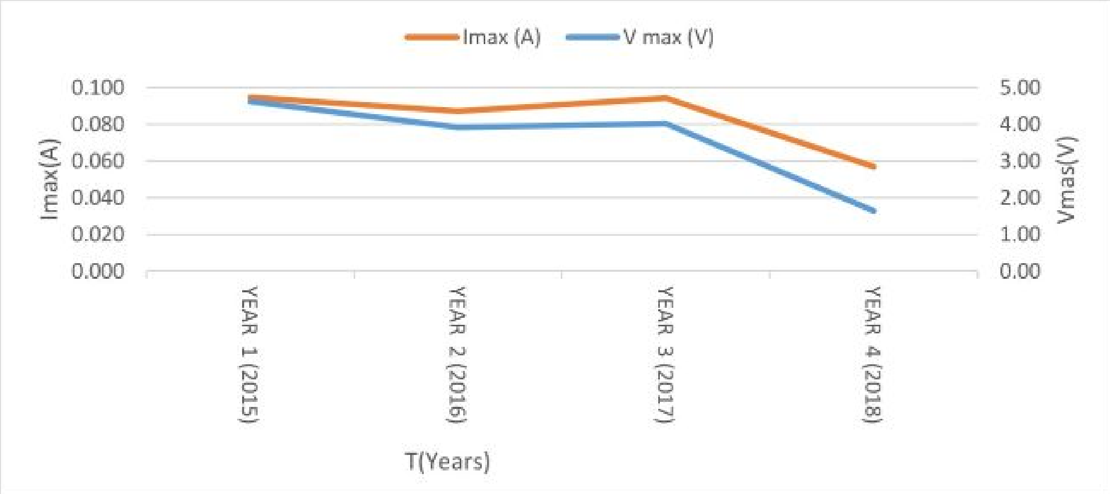

Figure 2: The yearly variation of maximum current and maximum voltage.

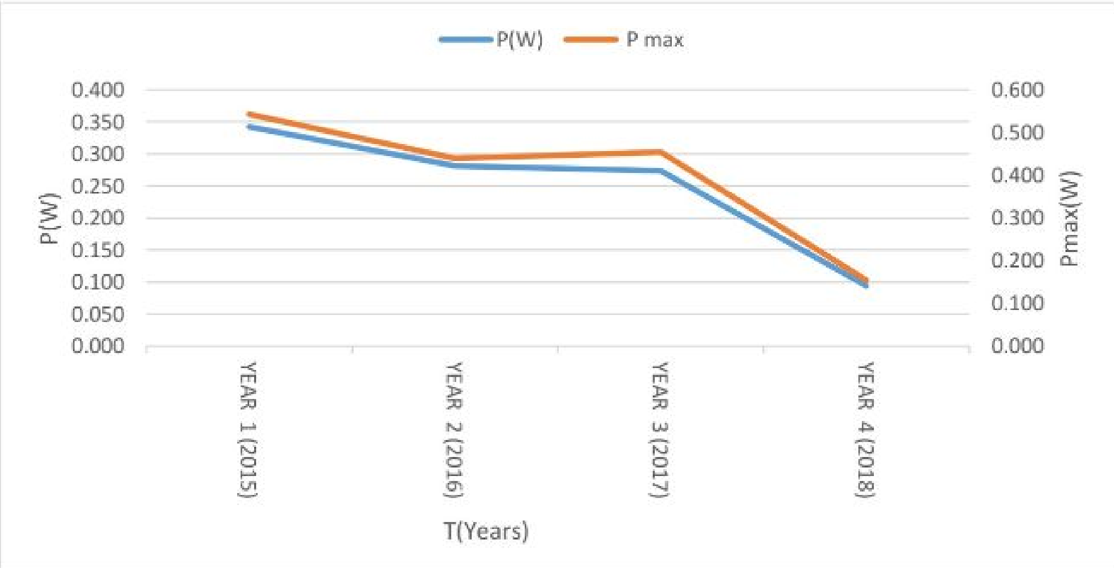

Figure 3: Yearly variation of Power (W) and Maximum Power (W)

In figure (1) shows the yearly variation of I-V characteristics of Short circuit currents and open circuit voltage, gradual degradation was observed by the open circuit voltage in 2015 from 4.62V to 3.91V In 2016 and further rise to 4.02V in 2017 then degraded to 1.64V in 2018.While the short circuit currents slightly increases from 2015 to 2017 by 0.001A and further increased by 0.006A in 2017,the rise in Isc from 2015 to 2017 was due to high in module temperature which accounted for the increases. Therefore, increases in Hg Tmod as seen in table has accounted for the increases for the three performance variable (Ezenwora,2016),then drastically degraded by 0.01A in 2018.

In Figure (2), Current at maximum (Imax) decreases slightly from 0.095A to 0.087A in 2016 and increases drastically to 0.94 A in 2017 and degraded in 2018 by 0.037A while Voltage at maximum decreases down from 4.62V in 2015 to 3.91V in 2016 and from here, an increases was observed by 0.12V in 2018 follows by a drastic degraded to 1.63V.

In figure (3), the Maximum power decreases by 0.1W from 2015 to 2016and a slight increases in 2016 from 0.439W to 0.455W and further degraded by 0.30W in 2018.The maximum current decreases by 0.008W between 2015 to 2016 and slightly increases to 0.094W in 2017 but finally degraded by 0.037W in 2018.

4.0 Conclusion

The yearly Analysis of degradation of mono-crystalline photovoltaic module was carried out in Minna local environment and the result shows that all the performance variables of the modules degraded significantly from year to year for the four years of studied. It was observed that the electrical parameters variables of the modules has an average degradation rate of 3.55V for Voc,0.039A for Isc,0.248W for P(W),3.55V for Vmax,0.083A for Imax and 0.398W for Pmax for the four years of study. Similarly, it was noticed from table 1 that, Voc and Isc has a yearly decreases of 0.7V and 0.001A from 2015 to 2016, 0.1V and 0.11A from 2016 to 2017,0.02.40V and 0.11A from 2017 t0 2018. Imax was observed to have decreases by 0.037A from 2017 to 2018 after the increments in the preceding years suggesting that Imax could begin to degrade after the third year. Furthermore, P and Pmax decreased by yearly average of 0.08W and 0.0.14W from 2015 to 2018.Module temperature was therefore observed to have significant influence on the general degradation of the module especially Voc and Vmax hence they increase when temperature decreased in 2015.In addition to the temperature effects on the degradation of the module is the solar irradiance which is seen to affect P, Pmax and Imax, hence, the increases when temperature and solar irradiance increased in the first year of study which is in line with early observation.(Ezenwora et al.,2018).By compering this result with that from (Pramod Rajput et al.,2016), with an average power degradation rate of 90 PV period of 22 years of outdoor exposure in the composite climate of India which was found to be about 1.9%/year with maximum rate of power degradation 4.1%/year and minimum is 0.3%/year. This is to concludes that they are correlate and it is therefore recommended that outdoor, yearly degradation studies should be carried out on all commercially available PV modules in every location of developing countries where this is not realizable .Result should furnish the policy makers, designers, PV power system installers the vital information on the degradations rate and lifespan of all commercially available PV modules for effective and reliable PV power system.

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