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THE ELECTRICAL PERFORMANCE ANALYSIS OF a-Si:H MODULES

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The electrical analysis of single junction amorphous silicon solar modules is carried out using outdoor monitoring technique. Like crystalline silicon PV modules, the electrical characterisation and performance of single junction amorphous silicon modules is best described by its current-voltage (IV) characteristic. However, IV curve has direct dependence on the type of PV technology and material properties used. Analysis reveals discrepancies in the modules performance parameter even though they are of similar technology. The aim of this work is to compare the electrical performance output of each modules, using electrical parameters with the aid of PVPM 100040C IV tracer. These results demonstrated the relevance of standardising the performance parameter for effective degradation analysis in a-Si:H.

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1. Introduction

In the early1970s, the solar communities went on research adventure to develop new solar energy materials and lower-cost solar conversion devices that will help increased the contribution of solar energy to national grid energy [5]. At the end of this adventure thin film solar material were developed, amorphous silicon solar cell is one of the most research out of all the thin film solar cell because of its technological nature. Amorphous has gained so much interest, since the late 2000's there have been an inflow of various kinds of amorphous silicon solar modules into the South Africa market with little or know out door assessment. Hence the need for this study, a-Si:H has better performance ratio at high temperature to crystalline solar cell, as well as better performance ratio when shaded, but it draw back has always be it high degradation and low efficiency. Hence there is an urgent need to address the degradation issues through outdoor assessment, this was addressed in this study, the table below is used as a baseline purpose.

Table 1.The initial performance parameters of the five modules investigated in this study and the STC corrected values.

Module	Measured					STC Corrected	
	I_{sc} (A)	V_{oc}(V)	P_{max} (W)	FF (%)	η_{max}(%)	P_{STC} (W)	η_{STC} (%)
1	1.11	21.7	12.8	52.8	9.6	14.0	10.5
2	1.02	22.2	12.3	53.9	9.2	13.8	10.3
3	1.01	23.3	10.8	46.0	8.1	12.3	9.2
4	0.91	22.1	8.6	43.1	5.4	9.7	7.3
5	0.92	23.2	10.4	48.6	7.8	11.9	8.9
Average	*0.99*	*22.5*	*11.0*	*48.9*	*8.0*	*12.3*	*9.3*
% Diff	*18.01*	*5.15*	*32.81*	*20.04*	*43.75*	*29.71*	*30.48*

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This study was scientifically innovated so as to show the importance of STC correction in degradation analysis. The performances of PV modules are usually monitored through parameters like maximum power, fill factor and efficiency and there after the analysis of the observed degradations are more often than not, rather superficial [3, 7, 8]. Innovative about this study is that the degradation analysis was done under control outdoor condition there by eliminating artifice in the results. The soiling, dust and grass particles, which were experienced during this monitoring process, were controlled by washing the modules every morning before measurements were done. Hotspots at first glance may seem rather benign, but could be detrimental to PV system performance, a fact not divulge by module providers due to their primary indoor assessment reliance. This in fact is doing tremendous harm to the PV industry in general and a-Si:H in particular.

2. Methodology

2.1. Electrical Diagnostics

An I-V tracer known as PVPM, type 10040C with SOZ-03#4858 inbuilt sensor device was used. Class 1 c-Si reference cell was used to measure plane-of-array (POA) irradiance. This device was used to measure all the electrical parameters of the modules. The modules were short-circuited when not undergoing measurement. This was done to comply with the IEC 1205 standard where modules are required to operate outdoor under short circuit for 60 sun-hours (1 sun-hour is equal to 1KWh/m^2) [2, 11, 13]. The IV tracer is able to measure the temperature that is approximately the same as the module's temperature with the help of Phox/Pt1000 sensor located to the back of the reference cell. But to previous unnecessary assumption temperature sensor was used to characterize the module temperature during each measurement. In order to account for the irregularity in daily irradiance as a function of time and other factors, which affect PV module performance, the measured P$_{\max}$ was standardized. The corrected P$_{\max}$ was obtained from equation 1, while the energy was calculated using equation 2.

$$P_{STC} = \left[P_{max}\left(\frac{1000}{H}\right) + \gamma(T_{mod} - 25°\text{C})\right] \tag{1}$$

$$E_{STC} = \left[P_{\max}\left(\frac{1000}{H}\right) + \gamma\left(T_{\text{mod}} - 25^{\circ}\text{C}\right)\right] \times \text{t} \tag{2}$$

WhereP_{max} is the actual power measured under irradiance H, $T_{mod}$is the module temperature and t is the time duration, while E_{STC} is the corrected energy generated. A temperature coefficient for power (γ) of 10.3 mW/°C was used [6]. This positive temperature coefficient is typical of a-Si:H in particular. In order to have a clear picture of how the I$_{sc}$ degraded with time, the measured I_{sc}datawhere corrected to STC using equation 3:

$$I_{STC} = \left[\frac{I_{SC} \times 100}{H}\right] + \left(25 - T_{Mod}\right) \times \alpha \tag{3}$$

Where$I_{sc}$is the measured short circuit current, I_{STC} is the STC corrected I_{sc} values and α (A/^{o}C)is the temperature coefficient.

3. Results and Discussions

3.1. Initial Degradation

For the purposes of this paper, the initial performance after 11 days when the modules received over 60 kWh/m^2 is termed as the initial measurements. During this time the modules' electrical performance degradation is clearly shown in Table 2. This decrease in the P$_{\max}$ is mainly due to the initial Staebler–Wronskieffect (SWE). Modules 1 and 3 showed the most significant degradation with 35% and 33% respectively.

Table 2. Presents the initial standardised degradation analysis of each panel.

Module	Max Power Day 1	Max Power Day 4	Max Power Day 11	Power reduction (%)
1	14.0	9.86	9.1	-35
2	13.8	9.40	10.2	-26
3	12.3	9.82	8.3	-33
4	9.7	7.62	8.4	-13
5	11.9	8.61	9.4	-21
Average	12.34	9.06	9.08	-25.6

Fig. 1 presents the corrected graph of the initial maximum power, the corrections were done using equation 1; It shows the degradation of the 5 modules that were observed in some of the modules due to daily temperature cycles. As early as region B (Day 2 – 4), hotspots could be observed on some of the modules.

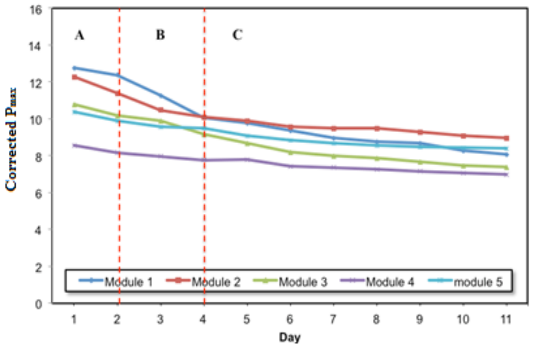

Fig. 1. Initial degradation of the modules due to daily temperature extremes.

On the first day of deployment, module 1 shows the highest power output while the least was module 4. The initial characterization was not chosen for performance analysis because of the high degradation rates, hence it is used for illustrative purpose. Fig. 2 presents the detailed degradation in the P_{max}.

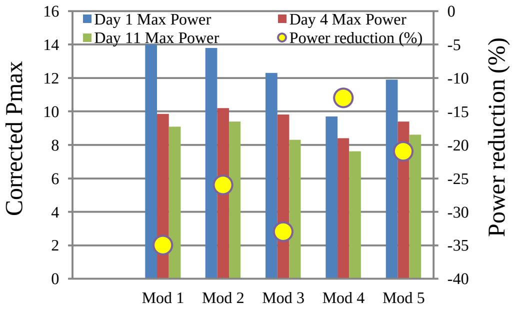

Fig.2. The initial standardised degradation analysis of each panel

The average power production decreases as the exposure time increases and it was observed that three of the modules performed below the average value of the entire modules, these modules include 3, 4 and 5. The percentage lost in the P_{max} is an indication of the degradation experienced by each module during this period, hence module 4 has the less degradation why module 1 is the most degraded PV module during this period.

3.2. Long Time Degradation

Furthermore, Table 3 shows the electrical efficiencies of each module, this gives the electrical output per unit area of the module and also presented in the table is the corrected module efficiencies at STC.Hence it illustrates the importance of correcting electrical parameter to STC value [6].

Table 3. Measured performance parameters of the five modules investigated in this study after 32 weeks; the STC corrected values are also listed for comparison.

Module	Measured					Corrected	
	I_{sc} (A)	V_{oc} (V)	P_{max} (W)	FF (%)	η_{max}(%)	P_{STC} (W)	η_{max} (%)
1	0.34	17.2	4.75	25.0	3.6	4.8	3.47
2	0.71	21.0	6.91	45.7	6.7	9.1	7.69
3	0.60	21.0	6.00	35.2	5.0	6.7	5.21
4	0.63	19.1	6.61	37.4	5.6	7.4	5.98
5	0.70	21.1	7.25	41.0	6.1	7.3	6.51
Average	0.596	19.88	6.304	36.86	5.4	7.06	5.772

The various electrical parameters have decreased significantly from what was presented in Table 1. In Table 1, module 1 had an efficiency of 10.5 %. However, at the end of week 32 its efficiency had decreased to 3.47 % this observation is abnormal for any high quality module. This observation is attributed to the high and continuous degradation rate of the module.

Table 4. Presents the long time (32 weeks) degradation analysis of each panel after standardization.

Module	P init (STC)	P 32wk (STC)	% change	FF init	FF 32wk	% change
1	9.1	4.8	-47.25	42.2	25.0	-40.76
2	10.2	9.1	-10.78	50	45.7	-8.60
3	8.3	6.7	-19.28	41.2	35.2	-14.56
4	8.4	7.4	-11.90	42.7	37.4	-21.78
5	9.4	7.3	-22.34	46.5	41.0	-12.41
Average	9.08	7.06	-22.31	44.52	35.26	-21.23

The terms, P init (STC) and FF init represent the P (STC) and FF values of each module at day 11. From Table 4, it shows thatthe average power production decreases as the exposure time increases and it was observed that three of the modules performed below the average value, two of these modules include 1 and 3. The percentage lost in the P_{max} is an indication of the degradation experience by each module during this period; this proves that module 2 has the less degradation why module 1 is the most degraded module.Table 5 presents the statistical analysis of the modules performance parameter after 32 weeks. From other measured date that is not presented in this paper, module 2 exhibits more stability from week 10 to week 32, the same phenomenon is seen in module 5. In addition, Table 5 presents the corrected maximum power and the percentage change in the modules efficiency. This helps to estimate the electrical degradation of each module in terms of efficiency at the end of week 32.

Table 5: Calculated parameter from measured performance parameters of the five modules investigated in this study after 32 weeks. It includes STC corrected values of P_{max} and percentage change in efficiency at STC.

Module	Corrected	
	P_{STC} (W)	%$\Delta\ \eta_{STC}$ (%)
1	4.8	59.30
2	9.1	25.34
3	6.7	33.15
4	7.4	18.08
5	7.3	19.40
Average	7.1	32.94

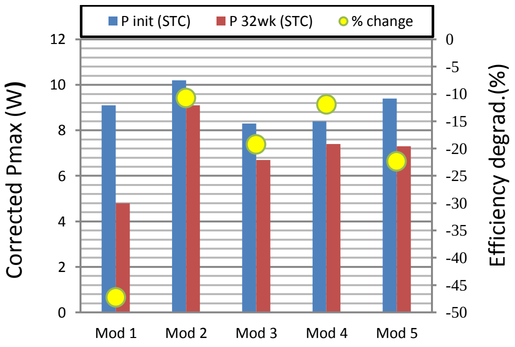

Fig. 3 Modules performance at the end of 32 weeks

The degradation process which occurred during the study has been established from the above results. It is clear that at the end of week 32, the performance of the modules fell to their lowest. As shown before, module 1 exhibits the worst degradation case, its P_{max} decreases from 9.1W to 4.8W between week 2 and week 32, which is a 47.3% percentage decrease in maximum power. Module 2 decreased from 10.2 W to 9.1W that is, 10.7% percentage difference reduction, for module 3 it experienced a decrease of 8.3W to 6.7W, which is equivalent to 19.3% percentage difference. While module 4 reduces from 8.4W to 7.45W that is 11.3% percentage difference decrease, but for module 5, a reduction of 9.4W to 7.3W is seen, this is about 22.3 % percentage difference reduction in P_{max}. The module with the less degradation becomes module 4 followed by module 2. While in terms of electrical efficiency module 2 was the best, followed by module 5 before module 4. The percentage changes in module 2 and 4 efficiency are slightly insignificant since a value of 25% is considered normal [4, 5], as such module 4 has the least percentage change at the end of weeks 32.

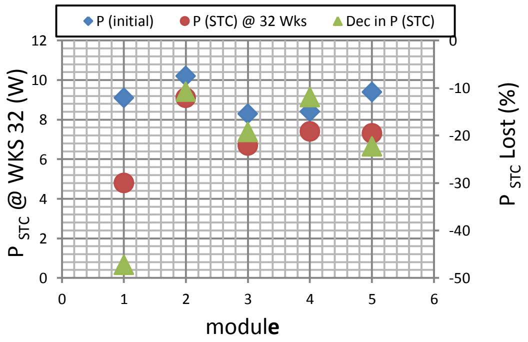

Fig 4. Corrected measured power output and power lost due to degradation

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In module 4, the P_{max} is slightly more than that of module 5, even though the initial P_{max} of module 5 was significantly more than that of module 4 but due to its high degradation rate observed in module 5.

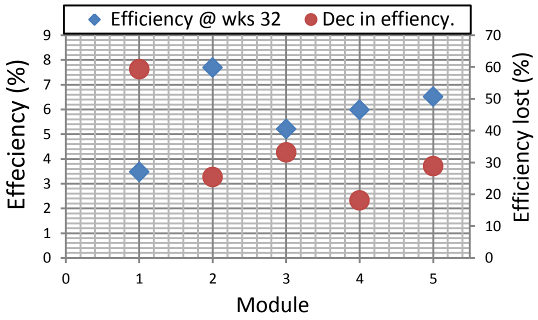

Fig 5. Modules efficiencies and efficiencies lost during outdoor installation period

4. Conclusions

In addition to the S-W effect, cracking of some modules occurred due to periodic temperature.Extremes, extensive hotspot formation was observed on all modules, resulting in high degradation.

This study dealt with electrical degradation analysis of a-Si:H. This paper demonstrates the effect of correcting performance parameter in diagnosing the electrical performances degradation of the PV module. The study examined the various performance parameters, including the open circuit current, open circuit voltages, fill factors, power generated and the efficiency of each module, as to have systematic and holistic understanding of how each module perform during outdoor deployment. In figure 4 and 5, best case scenario (module 2) degraded by 11.8% excluding the initial degradation stage and the module had approximately 7.8 % efficiency after stability was attained. On the other hand the worst case scenario (Module 1) had a degradation of 47.3% as represented by the % lost in P (STC), why the efficiency was approximately 3.5 % after the module attained stability.

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