Available online at www.elixirpublishers.com (Elixir International Journal)

Materials Science

Elixir Materials Science 159 (2021) 55717-55720

ISSN: 2229-712X

Study of the Impact of Dust on the Electrical Performance Parameters of CIGS Modules Installed in a Sahelian Environment

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ARTICLE INFO

Article history:
Received: 6 September 2021;
Received in revised form:
19 October 2021;
Accepted: 29 October 2021;

Keywords
Modulus,
Rate of change,
Electrical parameters,
Dust,
Cleaned,
Uncleaned.

ABSTRACT

This study presents the impact of dust on the electrical performance parameters of CIGS PV modules installed in a Sahelian environment. The study concerns two PV (photovoltaic) modules of the same technologies (CIGS), of the same power, (90W) each, of the same electrical parameters and manufactured by the same company. These modules, respectively denoted M_1 (SN-CIGS90) and M_2 (SN-CIGS90) were tested under the initial conditions to ensure their correct operation and to determine the initial values of the electrical parameters before exposure. After that, the modules are exposed under actual CERER operating conditions for three months, in which the module M_1 undergoes weekly cleaning and M_2 is exposed without cleaning for three months. The comparison of the variation rates obtained on the experimental values of the two modules shows that, like other technologies, the deposition of dust constituting the environmental constraint that most influences the electrical parameters of a CIGS module. In fact, the M_2, has respective variation rates of -38,581% for the maximum power (P_{max}) and -37,430% for the short-circuit current (Isc), +1.520% for the open circuit voltage and (V_{oc}) -3.309% for the form factor (FF), unlike the M_1 module, which undergoes the following variations: -7.5% for the P_{max} -3.163% for the I_{sc}, + 1.467% for the V_{oc} and -5,861% for the FF.

1. Introduction

When new, a PV module is characterized by its electrical parameters such as the short-circuit current; the open circuit voltage, the form factor and the maximum power it delivers. These data over time, when the module is exposed to sunlight with the actual operating conditions of the installation site. Indeed,during their uses depending on their location, PV modules are exposed to different climatic conditions (solar radiation, wind, rain, heat, etc.) which cause their deterioration and lead to a reduction in their performance [1]. Studies have shown that a simple deposit of dust on a module, even when new, reduces these electrical parameters. For example, a reduction in photovoltaic power of 17% on modules installed in Kuwait City was noted after six days without cleaning [2]. In our study, we showed the impact of dust on the electrical parameters of CIGS-type photovoltaic modules installed in the Sahelian environment. The comparison between the variation of the electrical performance parameters of two identical CIGS type modules, reference SN-CIGS 90, one of which undergoes weekly cleaning and the other exposed for a month without cleaning is the subject of this study.

2. Impact of Dust on the Electrical Characteristics of a PV Module

The impact of dust deposits on photovoltaic modules is much more felt at the level of electrical performance characteristics such as: IV and PV curves, open-circuit voltage (V_{co}), short-circuit current (I_{sc}) , the form factor and the maximum power (P_{max}). Shaharin et al have found that the power reduction due to dust deposition on the PV module can be up to 18% [3]. Hassan et al [4] studied the effect of airborne dust on the performance of a PV module and showed that a decrease in efficiency of 33.5% to 65.8% was achieved for an exposure from 1 to 6 months, respectively [5]. In a study by Zaihidee et al, [6], an accumulation of dust of 20 g / m^2 on a PV panel reduced the short circuit current by 15 to 21%, and the open circuit voltage from 2 to 6 %. El-Shobokshy and Hussein [7] showed that a cement dust deposit of 73 g / m^2 increased the short-circuit current of PV modules by 80%. To illustrate this, we present the results obtained during our research work on the Study of degradation and reliability of photovoltaic modules.

2.1Description of the Experimental Material

2.1.1CIGS modules

Table 1. Construction data of the two modules of each technology

Technology	Reference	V_{oc} (V)	I_{sc} (A)	P_{max} (W)	FF (%)
M_1 (CIGS)	SN-CIGS90	4.890	25.600	90	71,519
M_2 (CIGS)	SN-CIGS90	4.890	25.600	90	71,519

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To carry out this experimental study of the impact of dust on thin film modules, we purchased two CIGS technology modules, of the same power and manufactured by the same company. Table 1 above shows the construction data for each module.

Figure 1. CIGS flexible Modules

2.1.2 The measurement platform

The work was carried out on the site of the Renewable Energies Research Center of the Cheikh Anta DIOP University in Dakar where the two CIGS type modules were exposed.

The measurement platform also includes the ESL-Solar 500 electronic analyzer which is an electronic case specially developed for testing crystalline and thin film solar cells and modules. All the necessary load tests of solar modules can be performed with the ESL-Solar 500. It measures short circuit current, open circuit voltage, maximum current, maximum voltage, form factor, maximum power, efficiency, module temperature, irradiation…. All these functions are displayed on the clear multifunction

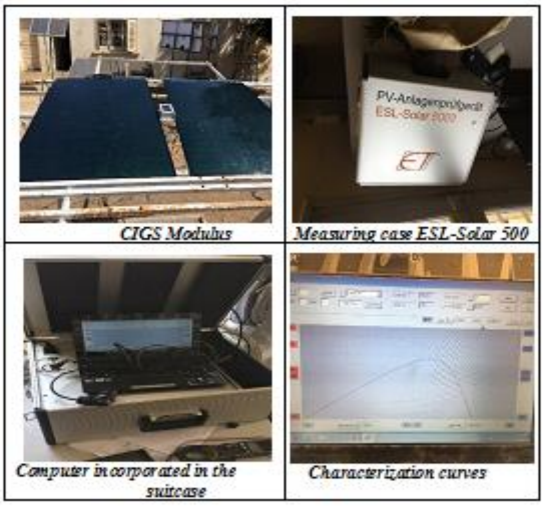

Figure 2. Measurement platform

2.2. Experimental Study

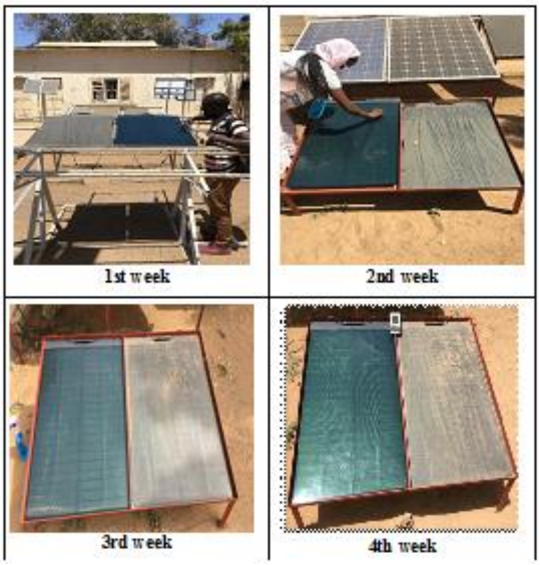

Figure 3. Exposure and weekly monitoring of modules.

After these tests, the modules are exposed on the CERER site where the M_1 module has undergone a weekly cleaning and the M_2 module is exposed without cleaning.

3. Results and Discussion

Using an "ESL-SOLAR-500" analyzer, we sought to determine the impact of dust deposition on the electrical performance parameters of the two modules. The study lasted a month during which the two modules M1 and M2 were exposed under actual operating conditions of the site where the module M1 undergoes weekly cleaning and the module M2 is exposed without being cleaned. The results obtained are presented in Table 2 and 3 below.

In our experimental studies below, we need to determine the rates of absolute and relative variations between the initial parameters and those obtained after the study.

For this, we used the following equations:

$$ARC = V_F - V_I \qquad (i)$$

$$RRC = \left(\frac{V_F - V_I}{V_I}\right) \times 100 \qquad (ii)$$

ARC, the absolute rate of change, RRC, the relative rate of change, V_F, the final value of the parameter and V_I, the initial value of the parameter. The following table 6 presents the results obtained on the CIGS modules after three exposures in the case of the deposit of dust (uncleaned module) and in the case where the module is cleaned every week.

Table 2. Variation of the various electrical parameters after three months of exposure of the module M_1 with cleaning.

M_1 (SN-CIGS90)	**Experimental conditions**	• Illuminance (W / m^2) 981: Initial measurement (characterization test) • Illuminance (W / m^2) 993: First measurement (after 1 month) • Illuminance (W / m^2) 998: Second measurement (after 2 months) • Illuminance (W / m^2) 972: Third measurement (after 3 months) • Temperature (° C) 63.1: Initial measurement (characterization test) • Temperature (° C) 64.1: First measurement (after 1 month) • Temperature (° C) 64.3: Second measurement (after 2 months) • Temperature (° C) 63.5: Third measurement (after 3 months)			
	Parameters	I_{sc} (A)	V_{oc} (V)	P (W)	F (%)
	Specific values	4.890	25.600	90.000	71,519
	Initial values	4,742	24,459	73,235	63,142
	Values after one month with cleaning	4.670	24,510	71,161	62,169
	Values after 2 months with cleaning	4,651	24,603	68,725	60,005
	Values after 3 months with cleaning	4,592	24,818	67,742	59,441

Table 3. Variation of the various electrical parameters after three months of exposure of the module M_2 without cleaning.

M_2 (SN-CIGS90)	**Experimental conditions**	• Illuminance (W / m^2) 995: Initial measurement (characterization test) • Illuminance (W / m^2) 918: First measurement (after 1 month) • Illuminance (W / m^2) 925: Second measurement (after 2 months) • Illuminance (W / m^2) 847: Third measurement (after 3 months) • Temperature (° C) 64.2: Initial measurement (characterization test) • Temperature (° C) 69.5: First measurement (after 1 month) • Temperature (° C) 68.5: Second measurement (after 2 months) • Temperature (° C) 64.3: Third measurement (after 3 months)			
	Parameters	**Isc (A)**	**V_{OC} (V)**	**P (W)**	**FF (%)**
	Specific values	4.890	25.600	90.000	71,999
	Initial values	4,646	23,814	70,999	64.172
	Values after one month without cleaning	3,908	23,541	59,512	64.688
	Values after 2 months without cleaning	3,279	24,00	49,033	62.306
	Values after 3 months without cleaning	2,907	24,176	43,607	62.048

Table 4: Results obtained on the modules, (a): Module M1 (SN-CIGS90), (b): Module M2 (SN-CIGS90)

Modules	**Parameters**	**Absolute rate of change**	**Relative rate of change**
a) Module M_1 (SN-CIGS90)	Pmax (W)	-5.493	-7,500 %
	Voc (V)	+0.359	+1,467 %
	Isc (A)	-0,150	-3,163 %
	FF (%)	-3,701	-5,861 %
b) Module M_2 (SN-CIGS90)	Pmax (W)	-27,392	-38,581 %
	Voc (V)	+0,362	+1,520 %
	Isc (A)	-1,739	-37,430 %
	FF (%)	-2.124	-3,309 %

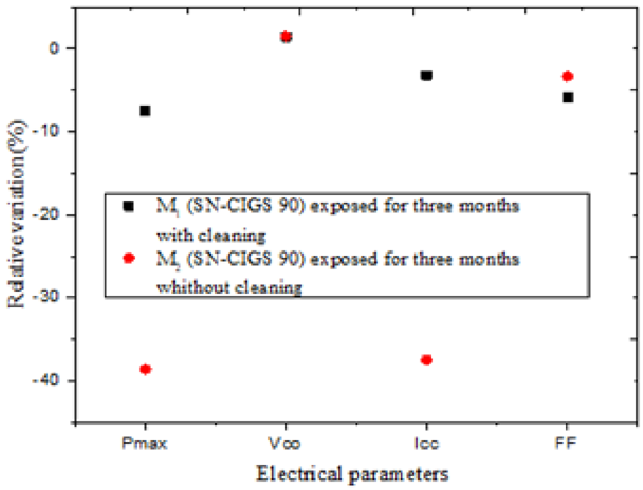

Figure 4. Comparison of the variation rates of the electrical parameters of the two modules after three months of explosion.

In both modules, there is a decrease in all electrical parameters except the open circuit voltage Voc, which shows a slight increase of +1 467% for the module exposed with cleaning and +1 520% for the module exposed without cleaning. For the other electrical parameters, the variation rates turn at 10% revolutions for the cleaned module with -7.5% for the maximum power (Pmax), -3.163% for the short-circuit current (Isc) and -5.861% for the form factor (FF), unlike the variations noted in the case of the uncleaned module of the same technology. In this case, we have a sharp decrease in parameters such as the maximum power and the short-circuit current after the three months of exposure with a variation of -38,581% for the maximum power (Pmax) and -37,430% for the short circuit current (Isc). For the form factor (FF), there is a slight decrease in-3.309%. These results obtained only like other technologies, the deposit of dust constituting the environmental factor which ranks the power and the short-circuit current of a CIGS-based solar panel the most.

Figure 4 below, shows the comparison between the different variations relating to the electrical performance characteristics of the module exposed for three months with cleaning and that exposed for three months without cleaning.

We note on this study made, that the deposit of dust, leads to a strong reduction of the electrical parameters. Apart from the open circuit voltage, which shows a slight increase, all the other parameters show a large variation for three months of exposure without cleaning, with the variation rate -38 581% for the maximum power, -37 430% for the short-circuit current and -3,309% for the form factor. It should also be noted that the degradation of these parameters is detected with less significant variation rates on the exposed module with cleaning: -7.5% for the maximum power, -3 163% for the short circuit current and -5 861% for the form factor. Comparison of these results shows that, like other technologies, dust deposition is the environmental factor that most influences the electrical parameters of a CIGS-based solar module.

The difference between the variations obtained on the exposed module with cleaning and on the exposed module without cleaning is very large. For example, for maximum power, the deviation is 31.081%. This shows that the module exposed for three months without cleaning, loses 31.081% more power than the module exposed with cleaning. This prompts us to seek the correlation between the mass of dust deposited and the rate of degradation obtained in future studies.

4. Conclusion

We note on this study made, that the deposit of dust, leads to a strong reduction of the electrical parameters. Apart from the open circuit voltage, which shows a slight increase, all the other parameters show a large variation for three months of exposure without cleaning, with the variation rate -38 581% for the maximum power, -37 430% for the short-circuit current and -3,309% for the form factor.

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