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Loss of Energy Yields of CIGS-Based Photovoltaic Modules, Caused by Dust Deposition

El Hadji Abdoulaye Niass1a, Awa Dieye1, Oumar Absatou Niasse1, Zakaria Makir2, Nacire Mbengue1, Pierre Tavarez1, Moulaye Diagne1, Zouhair Sofiani2, Bassirou Ba1

1 Cheikh Anta Diop University of Dakar, Faculty of Science and Technology, Department of Physics, Laboratory of Semiconductors and Solar Energy, Dakar, Senegal.

2 Hassan II Universities of Casablanca, Faculty of Sciences and Techniques of Mohammadia, Department of Physics, Laboratory of Materials and Energy and System control, Casablanca, Morocco

Abstract- The aim of this article is to study the energy yield losses of CIGS-based photovoltaic modules, caused by dust deposition. The study concerns two flexible PV (photovoltaic) modules of the same technologies (CIGS), of the same power, (90W) each, of the same efficiency η (14%) and manufactured by the same company SHENZHEN SHINE SOLAR CO, LTD. After characterization tests and determination of initial values, these modules, denoted respectively M1 (SN-CIGS90) and M2 (SN-CIGS90) were exposed in the real operating conditions of the Center for Studies and Research on Renewable Energies , located in Dakar for three months, corresponding to the duration of the experience. During these three months of research, the module M1 has undergone a weekly cleaning and M2 is exposed without cleaning. The comparison of the variation rates obtained on the experimental values of the two modules shows that the deposition of dust considerably reduces the energy yield of the CIGS solar modules. In fact, the M2 module, exposed for three months without cleaning, lost 29.289% of its efficiency while the M1 module, cleaned every week, lost only 09.164% of its efficiency. That's a difference of 20.125%.

Keywords- modulus, dust, cleaned, unclean, energy yields, rate of change.

I. INTRODUCTION

Solar modules installed in a Sahelian environment, in addition to very high ambient temperatures, encounter a high concentration of atmospheric dust deposition. This deposit of dust leads to the degradation of the performance of the modules installed in these environments.

The results found in the literature show that this loss of performance depends on the deposition time without cleaning, the exposure period and the dust adhesion of the exposed module surface.

A study carried out by Kalogirou et al in 2013 in Limassol en Chipres on three solar modules of the a-Si, poly-Si, and mono-Si types, shows after an exposure of 10 weeks power losses of 8%, 14% and 15% respectively. [1]

In our study, we showed the yield losses of flexible CIGS type photovoltaic modules, installed in Dakar, Senegal.

The comparison between the variation in performance of two identical CIGS-type modules, reference SN-CIGS 90, one of which undergoes weekly cleaning and the other exposed for three months without cleaning is the subject of this study.

II. STATE OF ART

The accumulation of dust deposits on photovoltaic modules is a phenomenon that hinders the development of solar energy, especially in desert countries such as the Sahel.

Indeed, this accumulation of dust causes a considerable loss of performance of PV modules.

Liqun et al found in 2012 that the power reduction due to dust deposition on a PV module installed in a semi-arid area in China in two weeks is 18.2% [2].

Schill et al studied the effect of dust on the performance of a PV module installed in an industrial area in Canaria, Spain and found that an efficiency reduction of 20% was achieved for an exposure of 9 months [3]. In a study conducted by Bajpaie Gupta et al, [4] in Nigeria, exposure of 4 months without cleaning a PV panel reduced its performance by 60%.

El-Shobokshy et al [5] found that a one month exposure of a PV CPV module to Riyade in Arabisaoudid triggered a 28.6% increase in short-circuit current, 30.6% in power maximum and 55% of the efficiency of this PV module.

For a two-month exposure of a single crystal PV module in the Bahraini desert, Som and Al- Alawi in 1992 showed a 41.4% reduction in short-circuit current. [6] In 2012, Sanusi showed in Nigeria a 25% reduction in peak power on an a-Si type module after 70 days of new working CIGS modules.

CIGS modules exhibited at CERER ESL-Solar 500 measuring case exposures. [7] In Hong Kong in 2006, Pang et al studied the impact of dust on a CIGS-based solar module after three exposures and showed a yield loss of 16.1%. [8].

To illustrate this, we present the results obtained during our research work on the study of energy yield losses on CIGS-based photovoltaic modules, attributed by dust deposition.

III. EXPERIMENTAL STUDY

1. Description of the Experimental material:

To carry out this experimental study of the energy yield loss on CIGS-based photovoltaic modules, caused by dust deposition, we purchased two new modules, with the same CIGS technologies, with the same power, with the same energy yield and manufactured by the same company. Table 1 above shows the construction data for each module.

The work was carried out on the site of the Renewable Energy Research Centre of the Cheikh Anta DIOP University in Dakar, where the two CIGS-type modules were exhibited.

The measurement platform also includes the electronic analyser ESL-Solar 500 which is an electronic case specially developed for testing solar cells and modules of all technologies. All the necessary load tests of solar modules can be performed with the ESL-Solar 500.

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

Technology	Reference	Vco (V)	Icc (A)	Pmax (W)	ɳ (%)
M1 (CIGS)	SN-CIGS 90	4.890	25.600	90	14
M2 (CIGS)	SNCI-GS90	4.890	25.600	90	14

It measures short circuit current, open circuit voltage, maximum current, maximum voltage, maximum power, yield, module temperature, irradiation.... All these functions are displayed on the clear multifunction screen of a computer coupled to the suitcase

(a) New working CIGS modules.

(b) CIGS modules exhibited at CERER.

(c) ESL-Solar 500 measuring case.
Fig 1. Experimental apparatus.

2. Experimental Study:
After this exposure, the modules were tested under the initial conditions at the renewable energy study and research centre to verify their correct functioning and to determine the initial values.

Then, the M1 module has undergone a weekly cleaning and the M2 module is exposed without cleaning during the three months of the experiment. Fig. 2 shows the state of the modules after each month of exposure.

(a) Status of modules after onemonth

(b) Status of modulesafter 2 months

(c) Status of modulesafter 3 months
Fig 2. State of modules M1 and M2 after each month of exposure.

IV. RESULTS AND DISCUSSIONS

Using the "ESL-SOLAR-500" analyser, we sought to determine the yield losses obtained on these two CIGS-type solar modules. The study lasted three months during which the two modules M1 and M2 were exposed in real operating conditions of the site where the module M1 has undergone a weekly cleaning and the module M2 is exposed without being cleaned. The results obtained are presented in Table 2 below.

Table 2. Results obtained after each month of exposure for modules M1 and M2.

Experimental conditions	M1 Modulus	• Illuminance (W / m2) 981: Initial measurement (characterization test) • Illuminance (W / m2) 993: First measurement (after 1 month) • Illuminance (W / m2) 998: Second measurement (after 2 months) • Illuminance (W / m2) 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)
	M2 Modulus	• Illuminance (W / m2) 995: Initial measurement (characterization test) • Illuminance (W / m2) 918: First measurement (after 1 month) • Illuminance (W / m2) 925: Second measurement (after 2 months) • Illuminance (W / m2) 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)

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	Modules	M1-SNCIGS90	M2-SNCIGS90
Yields [%]	Specific values	14	14
	Initial values	12.613	12.035
	Values after 1 month with cleaning	12.056	11.147
	Values after 2 month with cleaning	11.615	9.251
	Values after 3 month with cleaning	11.279	8.510

In our experimental studies below, we try to determine the absolute and relative rates of change between initial performance and those obtained after the study.

For this, we used the following equations:

$$ARC = V_F - V_I (1)$$

$$RRC = \left(\frac{V_F - V_I}{V_I}\right) x100 (2)$$

- ARC, the absolute rate of change,
- RRC, the relative rate of change,
- VF, the final value of the parameter and
- VI, the initial value of the parameter.

Table 3 below shows the results obtained on the CIGS modules after three months of exposure in the case of the deposit of dust (uncleaned module) and in the case where the module is cleaned every week.

Table 3. Results on the modules, (a): Module M1 (SN-CIGS90), (b): Module M2 (SN-CIGS90).

Modules	Durée d'exposition des modules	Taux de variation absolue	Taux de variation relative
(a) Module M1 (SN-CIGS90)	After one month	0.557	4.416%
	After two months	0.998	7.912%
	After three months	1.334	9.164 %
(b) Module M2 (SN-CIGS90)	After one month	0.888	7.378 %
	After two months	2.810	23.348 %
	After three months	3.525	29.289 %

We see after three months of exposure that the uncleaned module has a relative variation rate of 29.289%, against 09.164% for the cleaned module, ie a difference of 20.125%. The uncleaned module loses 3 times more yield than the cleaned module. These results show that like other technologies, dust deposition is the environmental factor that most degrades the performance of CIGS-based solar modules.

This is because the deposit of dust forms a mask on the surface of solar modules, which reflects certain solar rays and prevents them from entering the interior of the module. This leads to a considerable reduction in the number of charge carriers generated and consequently a decrease in the return.

Figure 4 below shows the comparison between the different relative variations in performance of the module exposed for three months with cleaning and that exposed for three months without cleaning.

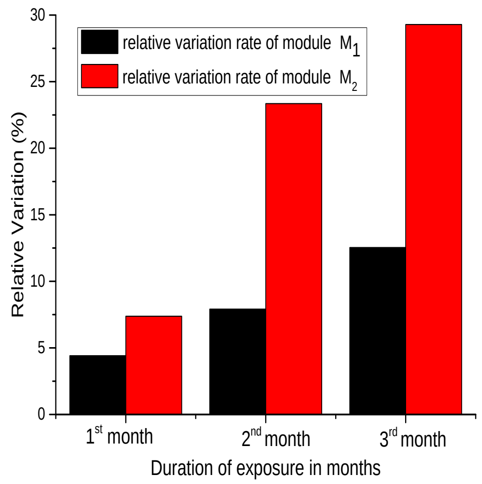

Fig 3. Comparison of the variation rates of the performance of the two modules after three months of explosion.

V. CONCLUSION

We note in this study, that the deposit of dust, leads to a strong decrease in the performances of solar modules based on CIGS.

In fact, the M2 module loses 29.289% of its performance after three months of exposure without cleaning; whereas the module M1 cleaned every week loses only 09.164% of its yield after the three months of exposure.

Comparison of these results shows that like other technologies, dust deposition is the environmental factor that most degrades the performance of CIGS-based solar modules.

The difference between these variations obtained on the exposed module with cleaning and on the exposed module without cleaning is very large (20.125%). This allows us to say that exposing solar modules without cleaning them frequently is a huge waste of energy.

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