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Study of the Degradation of PV Modules Installed in West Africa

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Abstract: In this paper, the degradation rate of monocrystalline, polycrystalline and amorphous PV modules is studied in a sub-Saharan zone in three periods: cleaning, no cleaning and rainy season. Studies that have been shown have increased series resistance. This is how the different cleaning phases of the crystalline module to the thin layer for not having decreased the maximum power of the module. Thus, the cleaning of the crystalline technology modules should be once a week and the micro-amorphous, once every three weeks. It is therefore preferable to observe a much longer cleaning period. It is confirmed in this study that soiling increases the rate of power degradation but that the modules are less affected by soiling under intense lighting. Our results are confirmed by other works [6]. Moreover they agree above 700 W / m², the impurities on very little influence on the maximum power of the modules, while below 400 W / m², the fall was about 25% of the initial power.

Keywords: Power, FF, Monocrystalline, Polycrystalline, Modules, Degradation

1. Introduction

PV modules have undergone many changes since the time of their creation, to improve their durability and performance. The first photovoltaic module developed by Bell Laboratories of the United States in 1955 used 3 cm diameter solar cells, encapsulated in silicone oil in a plastic housing and had efficiency of the order of 2% [1-4]. However, existing technologies are confronted with the harsh climate of hot areas especially in the Sahelian regions which are characterized by high temperatures and a high rate of dust.

An accurate forecast of energy delivery over time is of vital importance for the deployment and growth of the PV industry. There are two main cost factors. The first is the efficiency with which sunlight is converted into electrical energy and the other is the way this ratio is held relative to time. The parameter for the quantization of the power loss with respect to time is known as the degradation rate of the module. Each of these components undergoes degradation by different means when exposed to the hazards of the external environment. The percentage difference represents the reduction of the parameter. The rate of degradation parameters is given

respectively by the following equation [5]:

$$R_D(X)(\%?) = \left(1 - \frac{X}{X_0}\right) * 100 \quad (1)$$

Where $X = [I_{sc}, V_{oc}, P_{max}, FF]$ after the degradation and

$X_0 = [Isc_0, Voc_0, Pmax_0, FF_0]$ represents the reference values given by the manufacturers of the parameters under standard test conditions (STC). To discuss the influence of degradation modes on the module, it is convenient to compare the annual degradation rate given by the following equation [6]

$$R_D(X)(\%) = \frac{R_D(X)}{\Delta t} \quad (2)$$

Δt (years) is the exposure time in the field of photovoltaic modules of their operation until the end of the test.

We will present Influence of technology on power degradation of crystalline silicon PV modules and that of thin film technologies. We will discuss the degradation of electrical parameters (I_{sc}, V_{oc}, P_{max}, FF) compared to the technology.

2. Experimental Conditions

As previously indicated, the measured IV data of the different modules were extrapolated to standard test conditions so that we could compare their current performance from their initial performance at the time of installation (depending on the plate ratings signaling) which leads us to the percent degradation rates of the various electrical parameters such as output power (P_{max}), short-circuit current (I_{sc}) and open-circuit voltage (V_{oc}). We will first present the analysis of the performance of crystalline silicon PV modules followed by that of amorphous technologies. We will discuss the degradation of electrical parameters (P_{max}, I_{sc}, V_{oc}, FF, Vmax, I_{max}) compared to the technology. The PV modules have been characterized for a whole year following an experimental protocol that takes into account both seasons (dry and rainy).

The first period: corresponding to the dry season, the modules were not cleaned. The measures taken will make it possible to determine the average annual degradation rates of the modules. The main electrical performances considered here are: P_{max}, I_{cc}, V_{co} and FF.

The second period: corresponding to both the dry season and the rainy season, tests different cleaning periods for PV modules (daily, weekly / seasonal) and methods (dry or water).

A study on the effect of the dust and the periodicity of cleaning of the various modules has been made. The study aims to determine the optimal periodicity and method of cleaning each type of module according to the season. An experimental protocol was put in place and followed for one year. The main results obtained are as follows:

In dry periods, the crystalline modules must be cleaned with water once a week and the modules amorphous once every three weeks. Under these conditions, the annual energy gains, nevertheless the cost of cleaning, are at least 5%, compared to uncleaned modules, during rainy periods, the profits generated by regular cleaning of the modules are very low. We can generally remember that the modules do not need to be cleaned in this period.

3. Results and discussion

3.1. Influence of Technology on Power Degradation

The annual Pmax degradation rate for the different technologies is shown at the median of the crossbar. It is obvious that the degradation rate for polycrystalline 1 is higher followed by polycrystalline 2 and monocrystalline during periods of cleaning and without cleaning.According to the result tables, the micromorphic modules present a degradation rate of 0.4%, during the cleaning periods less than the monocrystalline and polycrystalline modules 2 respectively 0.8% and 0.9%.

During periods without cleaning, a degradation rate of 2.5% for micromorphic modules and rates varying from 1.7%, 2.2% and 2.5% for single crystal, polycrystalline modules. This result shows that the modules accumulating too much dust need to be cleaned but not with a lot of water to avoid humidity which will allow a better performance.

The rainy season corresponds to the period when one has much more degradations because at this time of the year in West Africa the temperatures are much higher which has a negative effect on the modules in terms of production. As we know, the modules are characterized for temperatures of 25° C and for each degree more of the latter we lose 0.4% of the power [7-10]

The decrease in the influence of soiling on high-illumination performance observed in the dry season is no longer observed here for all modules. In addition, the micro morph no longer appears in the rainy season, as the technology most affected by fouling.

In addition, the self-cleaning effect of the rain on a module will be less felt for a fine rain which a contrario can contribute to the clogging of the modules. Indeed, these fine water droplets will make the dust pasty thus increasing its adhesion on the surface of the modules.

Table 1. *Degradation vs technology.*

Pmax	Icc	Voc	FF
Period of cleaning			
0.85451	0.40897	1.2638	0.94258
Period without cleaning			
1.78329	2.74301	2.52169	2.21486
Raining season			
2.11662	1.5255	2.14535	1.9995

It is obvious that the degradation rate for the polycrystalline 2 is slightly higher than the monocrystalline which is verified by the analysis carried out by Jordan et al. [8], but this is not the case in periods without cleaning.

3.2. Influence of Electrics Parameters on Power Degradation

The degradation of the I-V parameters of a module differs from one technology to another and per period. Figure 2 at figure 5 show the degradation of electric parameters Pmax, Isc, Voc and FF polycrystalline monocrystalline and amorphous technology. The results obtained are recorded in tables.

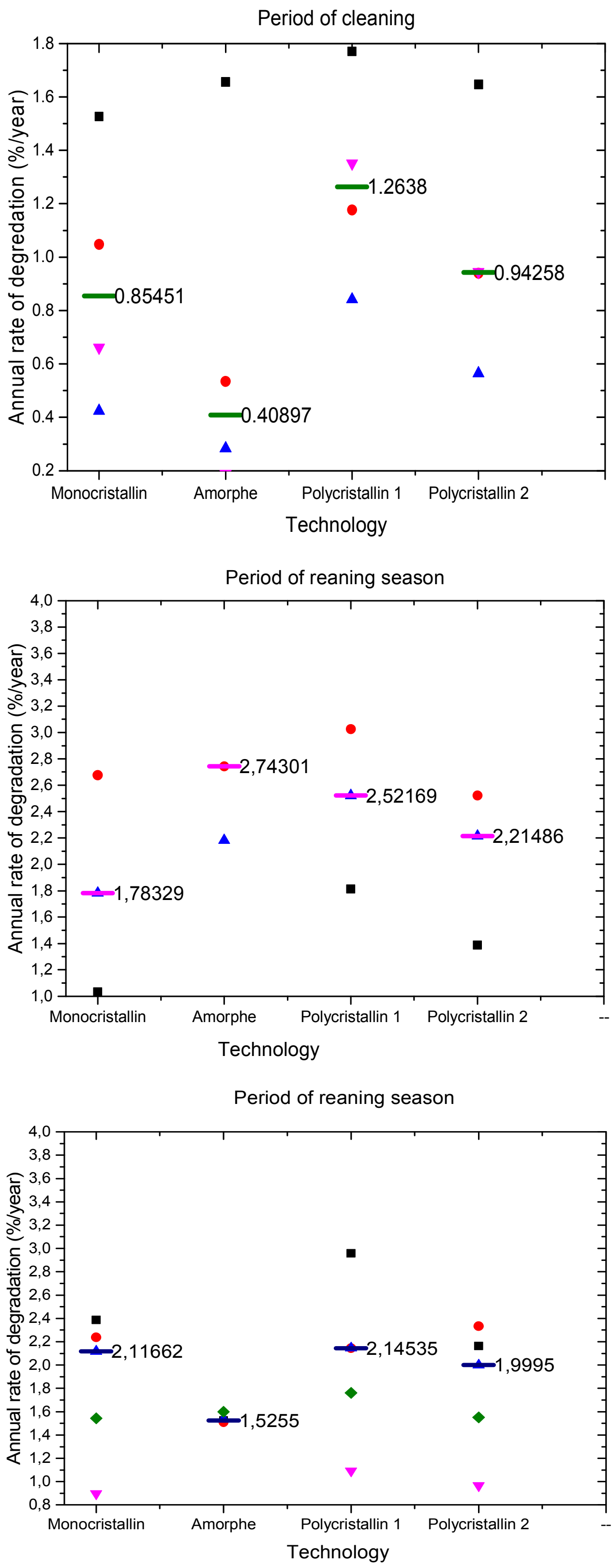

Figure 1. Influence of PV module technology on the degradation of maximum power.

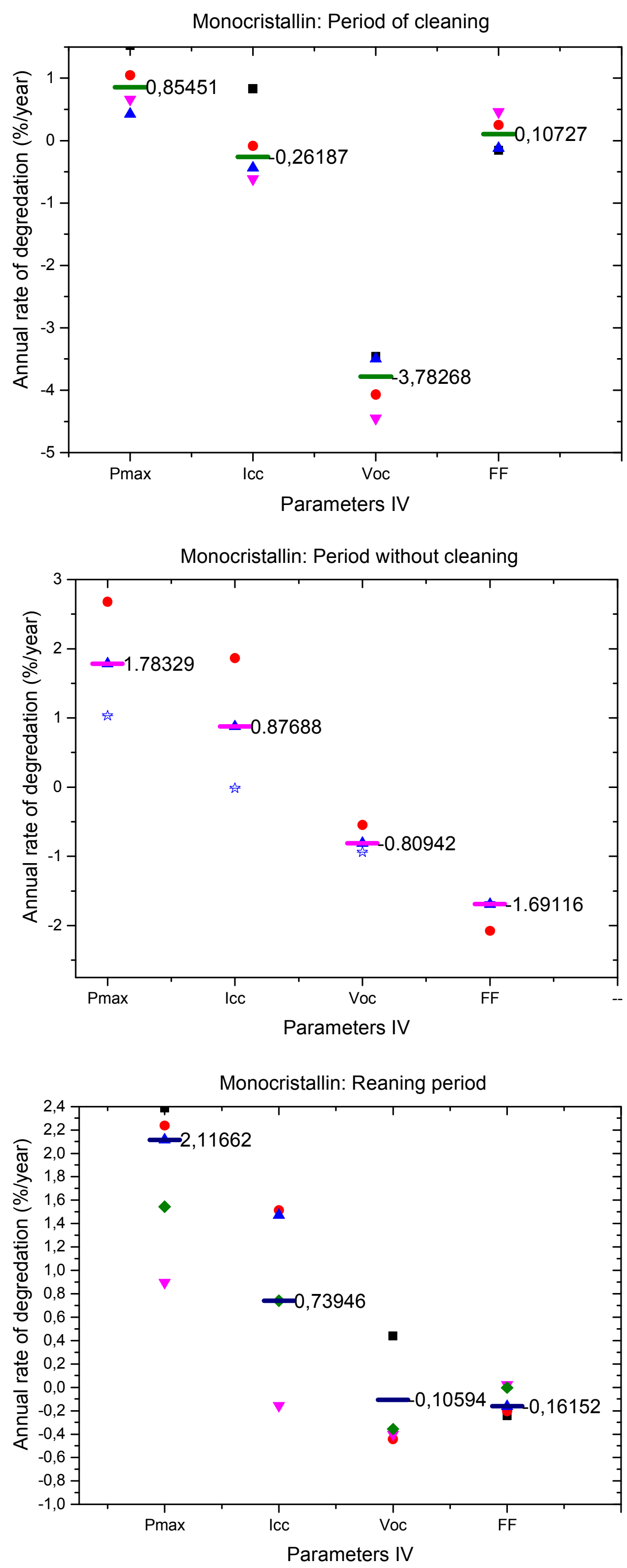

Figure 2. Degradation of I-V parameters (Isc, Voc& FF) for PV Monocrystalline Module technology.

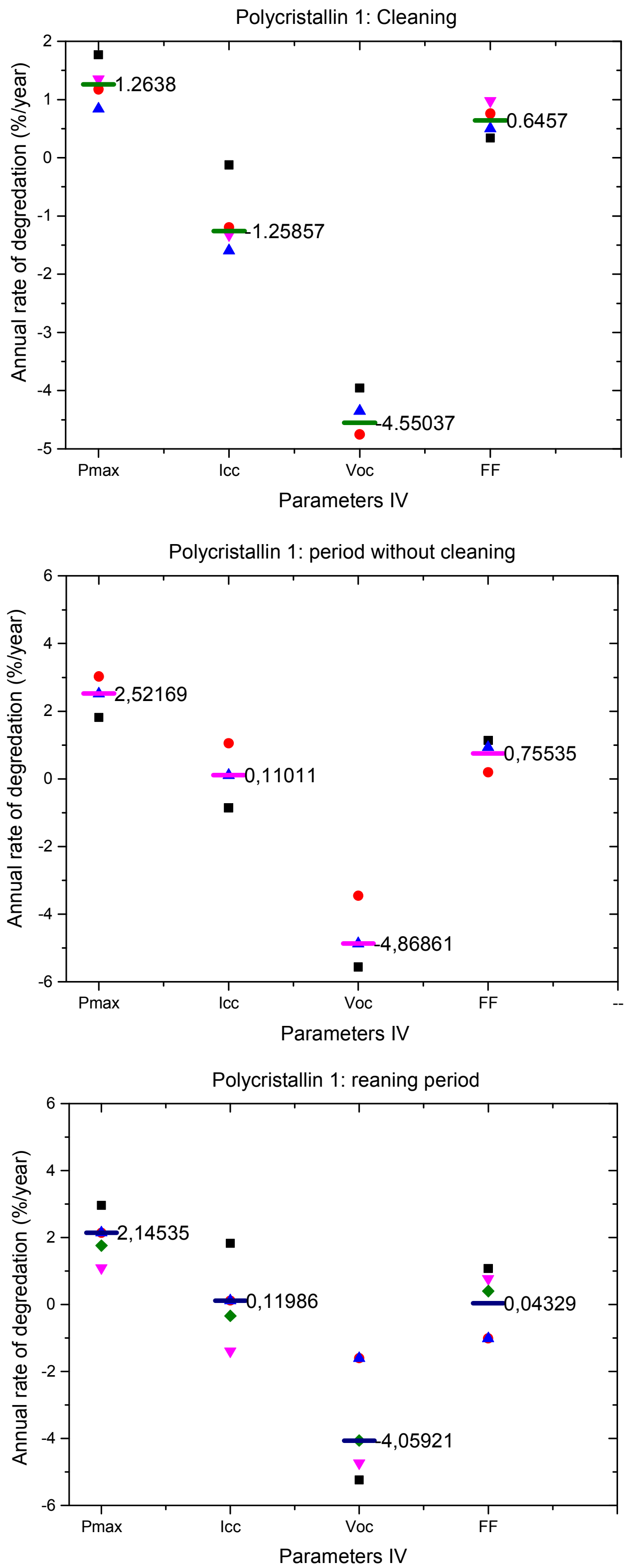

Figure 3. *Degradation of I-V parameters (Isc, Voc& FF) for different PV poly crystalline PV modules technologies 1.*

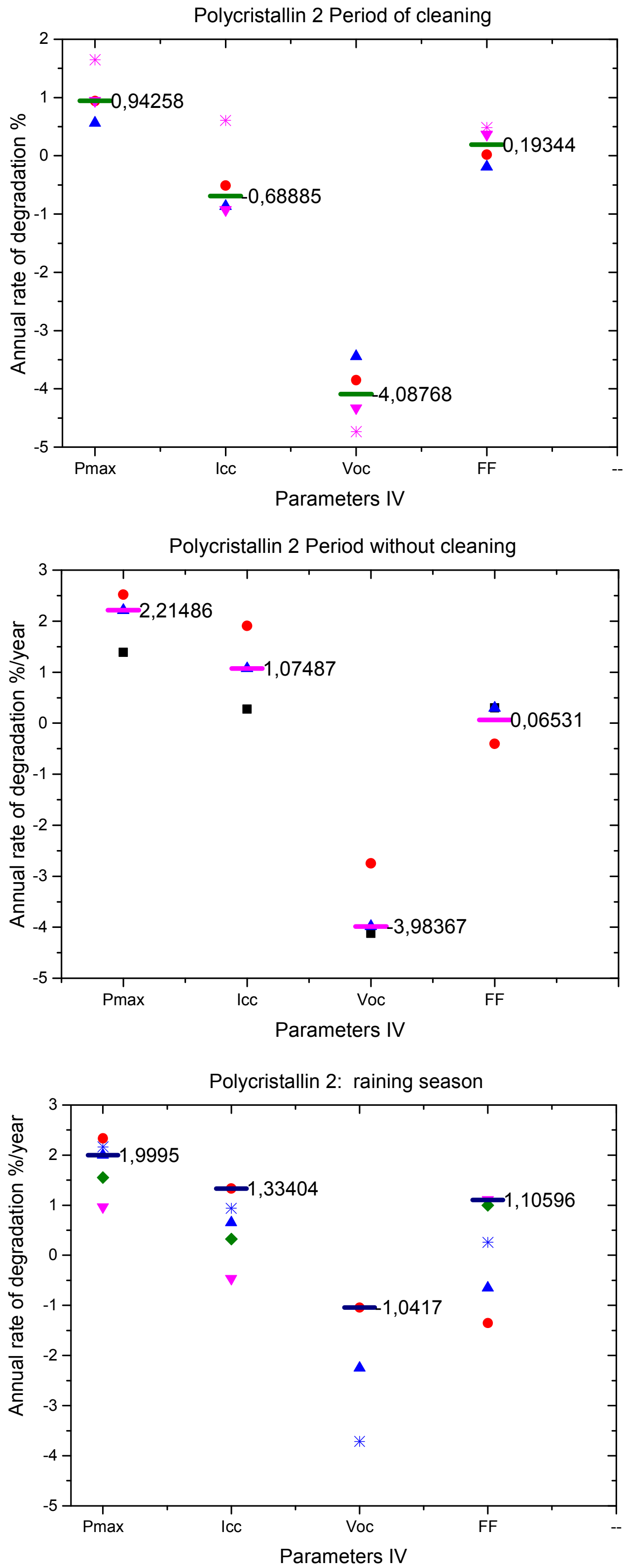

Figure 4. *Degradation of I-V parameters (Isc, Voc& FF) for different PV crystalline PV module technologies 2.*

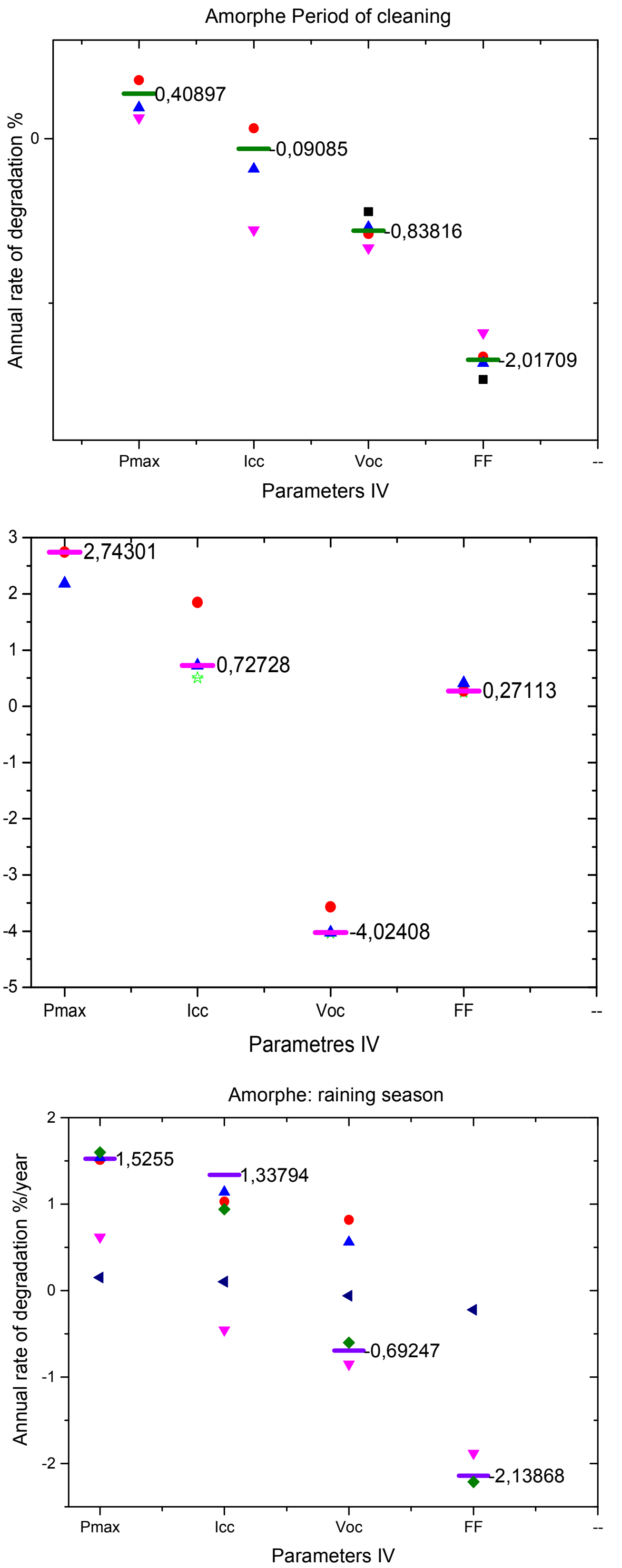

Figure 5. *Degradation of I-V parameters (Isc, V_{oc}& FF) for different PV crystalline PV module micromorph.*

Table 2. *Monocrystalline modules.*

Pmax	Icc	Voc	FF
Period of cleaning			
0.85451	0.26187	-3.78268	0.10727
Period without cleaning			
1.78329	0.87688	-0.80942	1.69115
Raining season			
2.11662	0.73946	0.10594	0.16152

Table. 3. *Polycrystalline Module 1.*

Pmax	Icc	Voc	FF
Period of cleaning			
1.2638	1.25857	-4.55037	0.6457
Period without cleaning			
2.52169	0.11011	-4.86861	0.75535
Rainy season			
2.14535	0.11988	-4.05921	0.04329

Table 4. *Poly cristallines 2.*

Pmax	Icc	Voc	FF
Period of cleaning			
0.94258	-0.68885	-4.08768	0.19344
Period without cleaning			
2.21486	1.07487	-3.98367	0.06531
Raining season			
1.9995	1.33404	-1.0417	1.10596

Table 5. *Microamorph.*

Pmax	Icc	Voc	FF
Period of cleaning			
0.40897	-0.09085	-0.83816	-2.01709
Period without cleaning			
2.74301	0.72728	-4.02408	0.27113
Raining season			
1.5255	1.33794	-0.69247	-2.13868

The monocrystalline modules have a power degradation rate of 0.85%, 1.78% during the cleaning period compared with 2.1% in the rainy season cf. Figure 2 and Table 2. As for the polycrystalline modules, the degradation rate is 1.28% during the cleaning period, 2.52% during the non-cleaning period compared to 2.14% during the rainy period, as shown in Figure 3 and the data from the Table 3. This same trend is observed with the polycrystalline modules 2 with a degradation rate of the order of 2.21% in period without cleaning more important when at the time of the rains (1.99). For modules with amorphous technology, it is the same observation with a degradation rate of about 2.74% greater than the rate recorded during the rainy season (1.52%) against 0.4% during the cleaning period as indicated on the Figure 5 and Table 5.

In general, the influence of soiling on the performance of all the technologies studied decreases when the solar irradiance increases.

The modules are therefore less affected by soiling under strong lighting. This finding was already made in the work of Maluta et al. [9], which showed in their study area that above

700 W / m², the soiling has a very low influence on the maximum power of the modules, whereas below 400 W / m², the fall observed was about 25% of the initial power. Now the analyzes show generally on the sun, the most frequent beach is that of 980 to 990 W / m² at 40% of the time, followed by that of 965 to 970 W / m². In dry periods, the crystalline modules should be cleaned with water once a week and the micromorphic modules once every three weeks.

In rainy weather the profits generated by regular cleaning of the modules are very low. We can generally remember that the modules do not need to be cleaned in this period.

4. Conclusion

In this article, existing technologies are confronted with the harsh climate of the sub-Sahelian hot zones which are characterized by high temperatures and a high rate of dust. It thus emerged that during almost amorphous technology has a lower degradation rate compared to other technologies, 0.4% during cleaning period, 15% during no-cleaning period and 18% during rainy season.

Also the results obtained on the influence of IV characteristics show that the modules need to be cleaned but not with a lot of water to avoid humidity. The highest Pmax degradation observed in the crystalline modules is most closely correlated with the degradation of Isc, followed by FF and finally Voc, which degrades little during the periods without cleaning and during the rainy season. So we can say that the degradation differs from one module to another and each module presents a behavior that is specific to it

References

[1] Munoz M. A., Alonso-Garcıa M. C., Nieves Vela, Chenlo F. Early degradation of silicon PV modules and guaranty conditions. Solar Energy 85,2011, 2264–2274.

[2] Vazquez M., Ignacio R. S. Photovoltaic Module Reliability Model Based on Field Degradation Studies. Progress in Photovoltaics: Research and Applications, 2008; 16:419–433.

[3] Fatou Dia, Nacire Mbengue, Omar Ngalla Sarr, Moulaye Diagne, Omar A. Niasse, Awa Dieye, Mor Niang, Bassirou Ba, Cheikh Sene, Model Associated with the Study of the Degradation Based on the Accelerated Test: A Literature Review, Open Journal of Applied Sciences, 2016, 6, 49-63

[4] Sadok M, Mehdaoui A. Outdoor testing of photovoltaic array in the Saharan region. Renewable Energy 2008;33. 2516–24.

[5] Shawn A. Fahrenbruch, Solar Bypass Diodes: Then and Now (Part 2) [online], Available:http://www.photovoltaic-production.com/1907/solar-bypass-diodes-then-and-now-part-2/,[Accessed Feb. 10, 2014]. E. Maluta and V. Sankaran, “Outdoor testing of amorphous and crystalline silicon solar panels at Thohoyandou,” Journal of Energy in Southern Africa, vol. 22, no. 3, p. 17, 2011

[6] E. Maluta and V. Sankaran, “Outdoor testing of amorphous and crystalline silicon solar panels at Thohoyandou,” Journal of Energy in Southern Africa, vol. 22, no. 3, p. 17, 2011

[7] Fatou Dia, Nacire Mbengue, Moulaye Diagne, Omar A. Niasse, Bassirou Ba and Cheikh Séne, Contribution to the Study of the Degradation of Modules PV in the Tropical Latitudes: Case of Senegal”, Research Journal of Applied Sciences, Engineering and Technology 12(4): 427-438, 2016

[8] P. Hülsmann, M. Heck, & M. Köhl, “Simulation of Water Vapor Ingress into PV-Modulesunder Different Climatic Conditions”. Journal of Materials, 2013,

[9] Omar Ngala Sarr, FABE Idrissa Barro, Oumar Absatou Niasse, Fatou Dia, Nacir Mbengue, Bassirou Ba, Cheikh SENE. Analysis of Failure Modes Effect and Criticality Analysis (FMECA): A Stand-Alone Photovoltaic System. *Science Journal of Energy Engineering*. Vol. 5, No. 2, 2017, pp. 40-47.

[10] Wohlgemuth J., Cunningham D., Nguyen A. M., Miller J. “Long Term Reliability of PV Modules”. Proc. 20th European Photovoltaic Solar Energy Conference, 1942-1946, 2005.