Analyze and Evaluate the Electrical Performance of PV Isofotón-100W Modules Exposed for a long Time in the Desert Environment

Slimane LARIBI[1] *, Touhami Ghaitaoui [1], Fatima Zohra ARAMA[1],
[1] Laboratoire de Développement Durable et Informatique (LDDI), Faculté des Sciences et de la Technologie. Université d'Adrar, Algeria 01000
*Corresponding author; Email: laribi.slimane@univ-adrar.edu.dz

Article Info

Article history:

Received 22/03/2023
Revised 05/05/2023
Accepted 28/05/2023

Keywords:

Degradation
Photovoltaic panels
Isofotón-100W
Electrical performance
Curves I-Vand P-V

ABSTRACT

The degradation of the electrical performance of photovoltaic panels Isofotón-100W exposed to the sun for a long period of about 10 years in a Saharan environment of Adrar was presented. In this article, we will present some experimental results obtained during the analysis of the I-V characteristics of some Isofotón-100W photovoltaic panels tested in the real conditions of the Saharan environment (Adrar region). The degradation of the electrical performance of the Isofotón-100W module is visualized through the analysis of the I-V and P-V characteristics experimentally or by visual field inspection of a renewable energy research unit in a Saharan environment. The physical parameters of the equation governing these characteristics were determined by the effective iteration method using only the information in the data sheet. The comparison between the experimental characteristic curves I-V and P-V of the photovoltaic modules (Isofotón-100W) and the reference in STC shows that the degradation of the electrical performances are due globally by the delamination and the discoloration of the EVA encapsulate after the long term exposure in a desert environment.

I. Introduction

In recent years, the demand for electricity has changed significantly, particularly in summer, reaching significant consumption peaks. This strong increase in demand is a direct consequence of the change in consumer habits and the improvement of the quality of life, as well as the drive given to the economic and industrial sector [1]. Possible solutions are: Renewable energies are clean, free and inexhaustible; but they are limited in available power. Among potential new sources of energy, photovoltaic conversion is extremely promising. Among potential new sources of energy, photovoltaic conversion is extremely promising. Solar cells can provide energy at levels ranging from a few mill watts to megawatts. They are reliable, stable and do not require maintenance [2-4]. The aging of photovoltaic cells and modules is a process that evolves naturally with the years of operation of the module in the field conditions (wind, rain, snow, heat, light ...) and therefore affects the performance of the module [5].

In this work, we propose some results obtained during the analysis of the I-V characteristics of some photovoltaic modules tested in the real conditions of the Saharan environment (Adrar region). The experimental tests were made on photovoltaic modules of type Isofotón-100W. The physical parameters of the equation governing these characteristics were determined by the effective iteration method using only the information in the data sheet.

The theoretical characteristics thus obtained were translated for the standard test conditions. These STC characteristics made it possible to estimate the performances of the modules tested for the same reference conditions. The analyzes of the characteristics of these modules, as well as the values of their degradation factors showed a marked reduction in their performances, in particular, the maximum powers and the form factors. The comparison between the experimental characteristic curves of the PV modules (Isofotón-100W) and the reference in STC illustrated a degradation on the electrical performances (Isc, Voc, Pmax, FF) which are due globally by the delamination and the discoloration of the EVA encapsulant after long-term exposure in a desert environment.

II. Model of I-V characteristic of a photovoltaic

Numerous mathematical models have been developed to represent their very strongly nonlinear behavior that results from that of the semiconductor junctions which are at the base of their realizations. In the literature, several models of the photovoltaic generator which differ from each other in the procedure and the number of parameters involved in the calculation of voltage and current of the photovoltaic generato [6].The characteristics at a single exponential (single diode model) of the current I = f (V) of a photovoltaic generator can be schematized as follows [5-7]:

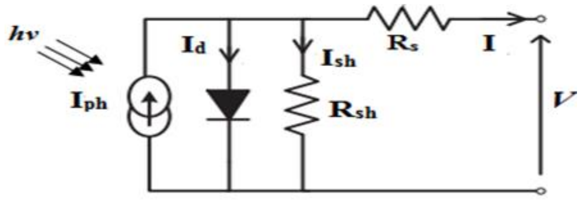

Figure. 1. Equivalent circuit of a photovoltaic generator [7], [8]

After circuit analysis, the voltage current equation is given as follows [9-12]:

$$I = I_{ph} - I_0\left[\exp\left(\frac{V + I R_s}{A V_T}\right) - 1\right] - \frac{V + IR_s}{R_{sh}} \quad (1)$$

Where I_{ph}: Current photo, I_0: Diode reverse saturation current, R_s: Module series resistance, R_{sh}: Module shunt resistance , A: Ideality factor of the junction, V_T: Thermal voltage for a diode model (thermodynamic potential). The photovoltaic module physical parameters ; I_{ph}; I_0; R_s et R_{sh} are determined according to the electrical parameters; I_{sh};V_{oc}; I_{mp} ; V_{mp} et A by the iteration method. The objective is to find the Isofotón-100W model physical parameters such that the I-V curve obtained by the simulation corresponds exactly to the experimental curve.

Figure 3 represents a comparison between the experimental curve and Isofotón-100W PV module simulation based on experimental input data (T = 36.1°C et G=843 w/m²).

It is observed that the experimental and simulated results are precisely matched in three key points: Short-circuit I_{sh}, the open-circuit voltage V_{oc} and the maximum power P_{max} .

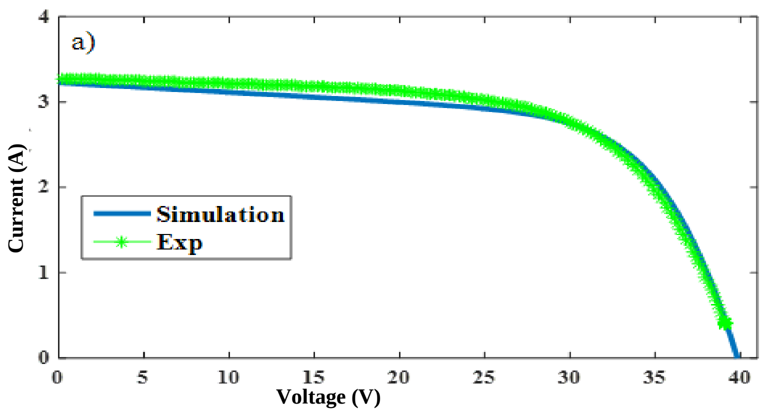

Figure.2. Isofotón-100W PV module experimental and theoretical I -V characteristics.

A. Calculate the performance parameters degradation rates

The degradation factor is theoretically allowed to estimate the rate of change of each parameter (P_{max}, V_{mp}, I_{sh}, and FF) according to its initial value. The global and annual degradation rates are calculated by the following expression.[10][11]

$$FD(\%) = \left(1 - \frac{X(t_n)}{X(t_0)}\right) * 100 \quad (2)$$

$$AFD(\%) = \frac{FD}{\Delta T} * 100 \quad (3)$$

Where, $X(t_n)$ represents the parameter values after degradation in (STC) at times(t_n), and $X(t_0)$ illustrates the reference parameter values given by the constructor in STC at times t_0 .

III. EXPERIMENTAL SECTION

A. Experimental testing platform description

All experimental tests were carried out in the Renewable Energy Research Unit (URERMS) Adrar, Algeria. We chose to work on three Isofotón-100W panels, which are exposed to the sun for a long time of 10 years.

These panels are tested with the north-south orientation with inclination of the horizontal plane at the latitude of the place. For test the Isofotón-100W PV modules characteristics exposed to natural conditions, the MP-160 (I-V) tracer is the optimal solution for measuring the PV modules performance with a high level of accuracy Figure 3.

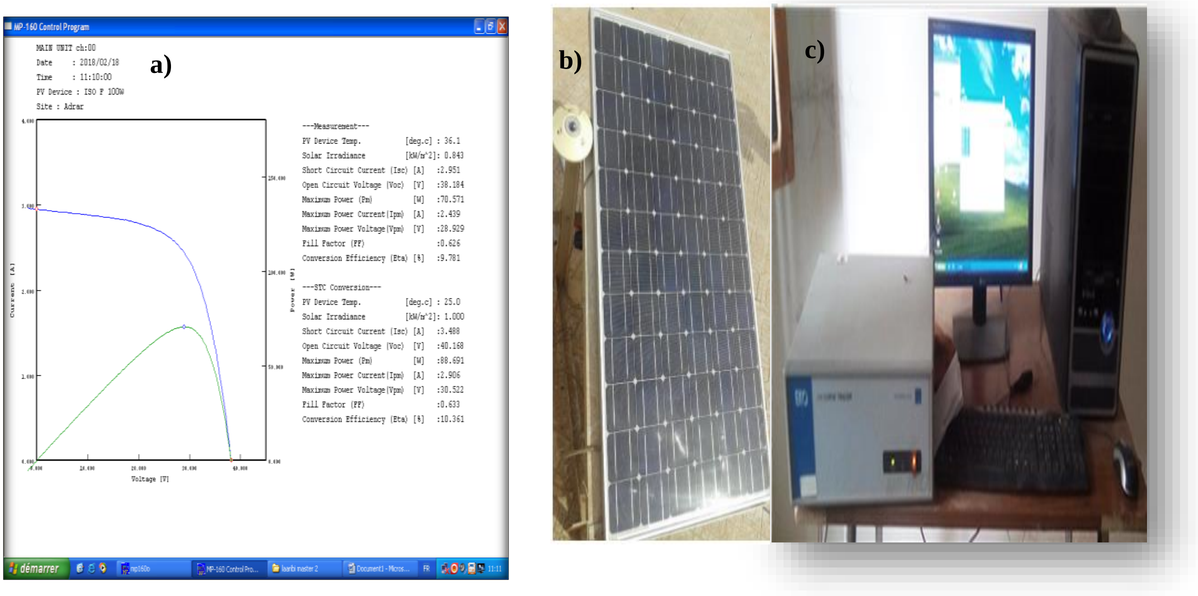

Figure.3. Measurement platform; a) MP160 control program; b) PV panl Isofotón-100W ; c) MP-160 (I-V) tracer

During the test period, the acquisition and translation of the measurements to the standard test condition STC of each PV module was performed by the MP160 I-V tracer. The solar radiation and the temperature of the exposed modules are measured by the pyranometer and the thermocouple fixed on the rear photovoltaic module face. The measurements were saved in Excel format, then the I-V curves are drawn with MATLAB software.

B. PV Isofotón-100W modules degradation analysis

The evaluation of the degradation requires the external measurements conversion to the Standard Test Condition (STC) in accordance with the International Electrotechnical Commission Standard (IEC 60891) [12], for comparison with reference data (nominal data) given by the photovoltaic panels manufacturer. In this work, the acquisition and measurements translation to the standard test condition of each PV module are provided by the MP160 I-V tracer in order to give the correlation between the visual inspection (Figure 4) and the electrical performances degradation of the three PV panels Isofotón-100W which are exposed to the sun for a long time at URERMS-Adrar.

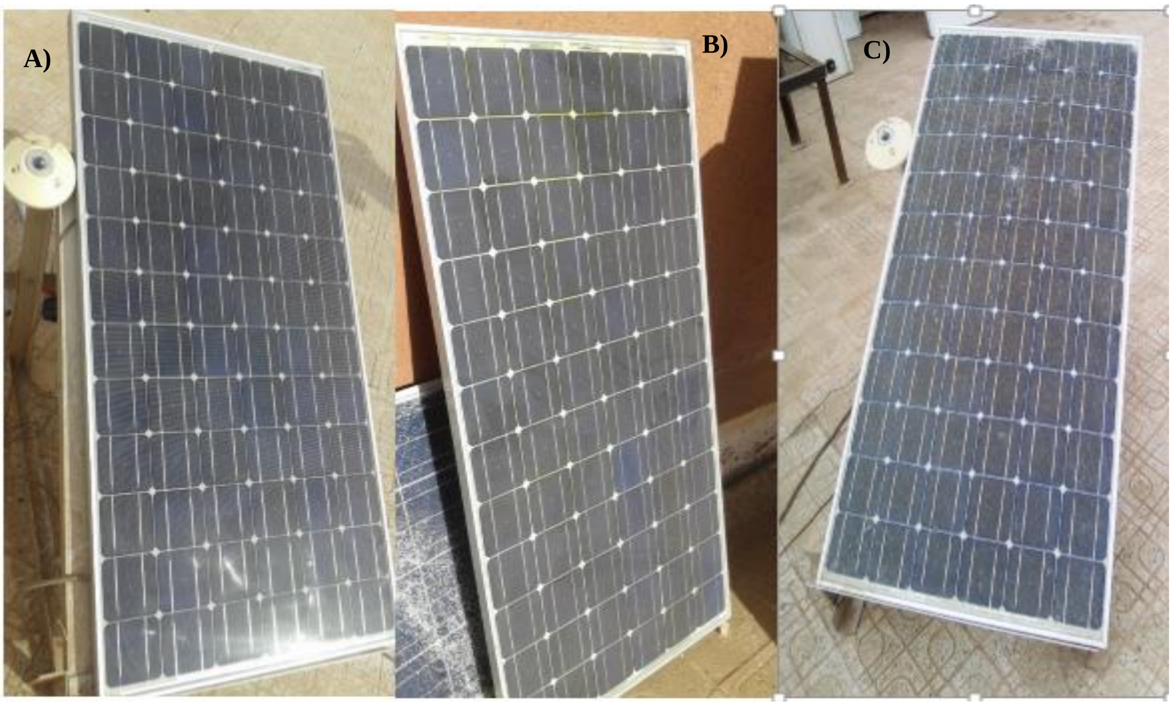

Figure .4. Different modules Isofotón-100W are tested: Module (A) in the left (Discoloration EVA), Module (B) in the medium (Discoloration (yellow) of the encapsule), Module (C) in the right (broken glass)

A. I-V and P-V characteristics results of the Isofotón-100W module

To evaluate the Isofotón-100W module degradation after long-term exposure in climatic conditions saharan we use the I-V and P-V characteristic. The measured electrical parameters of three PV modules (I-V and P-V curve) with each defects PV panels (module (A) Discoloration EVA), module (B) Discoloration (yellow) of the encapsule), module (C) broken glass.

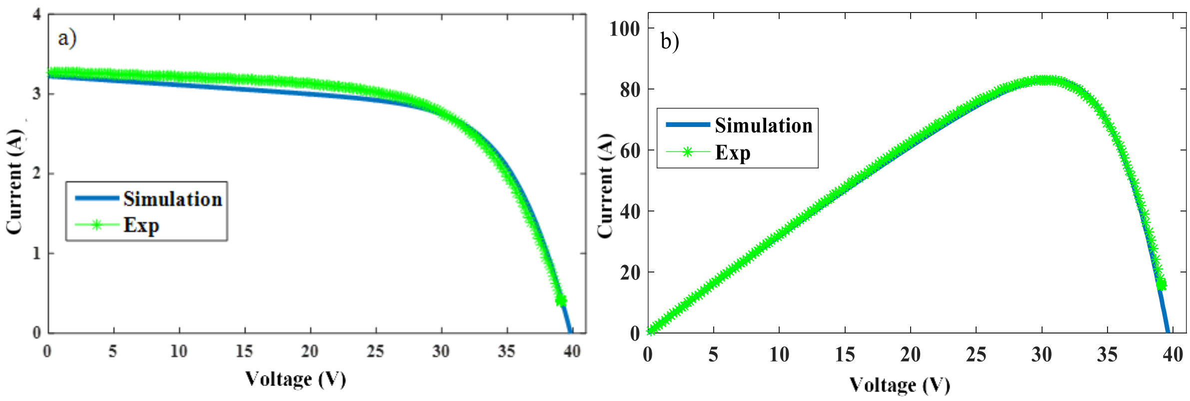

Figure. 5. Comparison between the experimental of Isofotón-100W model (A) and simulation in STC, a) I-V characteristic curves, b) P-V characteristic curves

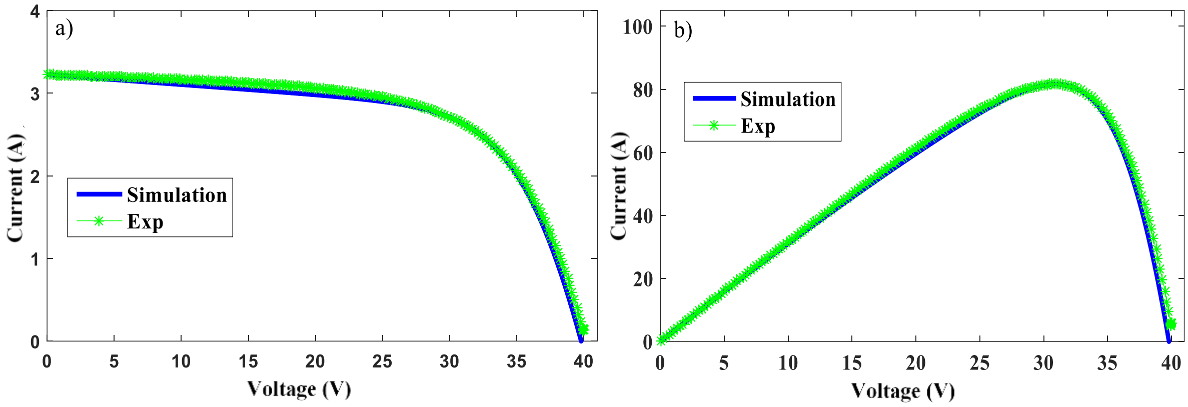

Figure. 6. Comparison between the experimental of Isofotón-100W model (B) and simulation in STC, a) I-V characteristic curves, b) P-V characteristic curves.

Figures 5, 6, show a comparison between the experimental curves in STC and that obtained by the simulation. It is observed that the simulated and experimental results corresponds exactly to three key points; the short circuit current I_{cc}, the open circuit Voltage V_{oc}, the maximum power P_{max}. What is allowed to say that the physical parameters obtained by the effective iteration method is very close to the actual physical parameters of the constrictor.

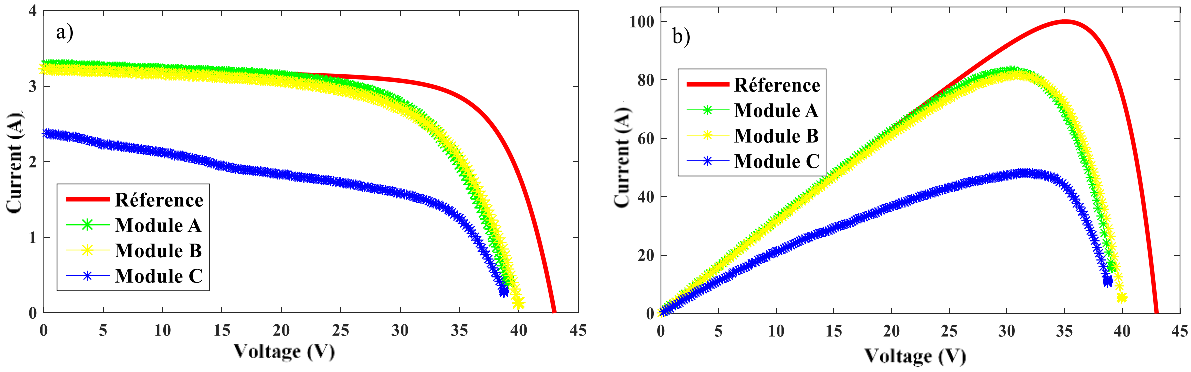

Figure 7. Comparison between the experimental of Isofotón-100W model and the reference in STC, a) I-V characteristic curves, b) P-V characteristic curves

Figures 7, represent a comparison between the experimental results of the Isofotón-100W modules and the reference. It is observed that the electrical performance of the Isofotón-100W PV module (Icc Voc, Pmax) has been degraded compared to the reference module and this can render to the EVA declaration for the PV module (A), discoloration (yellow) of the encapsule on the PV module (B) and the broken glass of the photovoltaic cells (C).

The Table. 1 below shows the comparison of electrical performance between the reference model and the degraded modules.

Table 1. The evolution of the Isofotón-100W modules performance parameters tested.

Parameters	Reference module	Module A	Module B	Module C
Maximum power P_{max} [W]	100	83.970	81.622	48.013
Optimum current I_{mp} [A]	2.807	2.731	2.650	1.505
Optimum voltage V_{mp} [V]	34	30.402	30.799	31.902
Short circuit current I_{sc} [A]	3.270	3.280	3.224	2.418
Voltage in open circuit V_{oc} [V]	43.200	39.970	40.224	39.592
Form factor FF [%]	0.675	0.633	0.629	0.502
Ideality factor of the junction A	1.5	1.5	1.5	-
Resistance series of module R_s [Ω]	0.2765	0.7700	0.6800	-
Shunt resistance of module R_{sh} [Ω]	187.1708	91.9868	82.8367	-

Table 2. The global and annual degradation for the different electrical parameters of PV Isofotón-100W modules tested

Parameters	Module A		Module B		Module C	
	FD(%)	AFD(%)	FD(%)	AFD(%)	FD(%)	AFD(%)
Maximum power P_{max} [W]	16.03	1.78	18.37	2.04	51.98	5.77
Optimum current I_{mp} [A]	2.70	0.3	5.59	0.62	46.38	5.15
Optimum voltage V_{mp} [V]	10.58	1.17	9.41	1.04	6.17	0.68
Short circuit current I_{sc} [A]	-0.305	-0.033	1.41	0.15	26.05	2.89
Voltage in open circuit V_{oc} [V]	7.47	0.83	6.88	0.76	8.35	0.92
Form factor FF [%]	6.22	0.69	6.81	0.75	25.62	2.84

Table 2 presents the global (FD) and annual (AFD) degradation for the different electrical parameters (P_m,V_{mp}, I_{mp},FF) of PV Isofotón-100W modules.

1- The module (A) is characterized by a low material discoloration that is used for encapsulation, generally it is made of Ethylene Vinyl Acetate (EVA) or the adhesive material between the glass and the cells. It leads to the transmittance modification of the cells encapsulated and consequently the performance losses (Table 2), where Pmax is 16.03%, the current Isc (-0.305%), and form factor FF (6.22%). Negative value indicates increased performance with over time [10].

2- The module (B) is characterized by a discoloration (yellow) of the encapsulant, which causes performance losses where Pmax is equal to (18.73%), the current Isc (1.41%), and form factor FF (6.21 %). This degradation is due to the change of material color from white to yellow, under the effect of UV irradiation and high temperature.

3- The module (C) has breaking and breaking glass induced by the effect of handling the transport. The global performance degradation are (51.98%) for Pmax, (26.05%) for the current Isc and (25.62%) for the form factor FF.

The annual degradation of the maximum power of each three PV Isofotón-100W modules (A, B and C) respectively is 1.78%, 2.04%, 5.77%. This degradation is due to the discoloration (EVA) which caused by the effect of UV irradiation and high temperature

IV. Conclusion

The main purpose of this work is to study the degradation of Isofotón-100W PV modules through the estimation of physical parameters and electrical performance. To calculate these parameters, we used a simple and fast effective iteration method to simulate the photovoltaic system for any conditions, in case it is not possible to perform experimental tests, using only the information of Datasheet.

In this case, we presented the measurement platform to characterize some photovoltaic modules exposed to the sun for a long period of time in the unit of research in renewable energy in a saharan environment (URERMS-Adrar).

The degradation of the photovoltaic modules electrical performance (Isc, Voc, Pmax, FF) is visualized either by visual inspection or by the I-V characteristics analysis.

According to the analysis by PV modules visual inspection concluded that the degradation may be due by; the discoloration (yellow) of the encapsulate under the effect of UV irradiation.

The comparison between the experimental curves in STC and that obtained by the simulation shows that the physical parameters obtained by the effective iteration method is very close to the actual physical parameters of constrictor.

The comparison between the experimental PV modules (Isofotón-100W) characteristic curves and the reference in STC illustrated that the degradation on the electrical performances are due globally by the delamination and discoloration of the EVA encapsulant after the long-term exposure in a desert environment.

References

[1] Bouraiou A, Necaibia A, Boutasseta N, Mekhilef S, Dabou R, Ziane A, et al. Status of renewable energy potential and utilization in Algeria. J Clean Prod 2020;246:119011. doi:10.1016/J.JCLEPRO.2019.119011.

[2] Ghaitaoui T, Laribi S, Arama F Z & Benabdelkrim B. Evaluation experimental of the impact of Saharan climate conditions on the infinity organic photovoltaic module performance. Australian Journal of Electrical and Electronics Engineering 2022;1-10; https://doi.org/10.1080/1448837X.2022.2108585.

[3] F Zohra Arama, Slimane Laribi, Touhami Ghaitaoui, A Control Method using Artificial Intelligence in Wind Energy Conversion System,Algerian Journal of Renewable Energy and Sustainable Development, olume 1 Numéro 1 Pages 60-68

[4] A. Bouraiou *et al.*, “Analysis and evaluation of the impact of climatic conditions on the photovoltaic modules performance in the desert environment,” *Energy Convers. Manag.*, vol. 106, pp. 1345–1355, 2015.

[5] A. Faba, S. Gaiotto, and G. M. Lozito, “A novel technique for online monitoring of photovoltaic devices degradation,” *Sol. Energy*, vol. 158, pp. 520–527, 2017.

[6] J. D. Bastidas-Rodriguez, E. Franco, G. Petrone, C. A. Ramos-Paja, and G. Spagnuolo, “Quantification of photovoltaic module degradation using model based indicators,” *Math. Comput. Simul.*, vol. 131, pp. 101–113, 2017.

[7] B Benabdelkrim, A Benattilah, T Ghaitaoui, K Hammaoui , Experimental Analysis of a Photovoltaic Power Plant in a Desert Environment–Adrar area ,Algerian Journal of Renewable Energy and Sustainable Development 3 (1), 85-96

[8] Sahouane N, Dabou R, Ziane A, Neçaibia A, Bouraiou A, Rouabhia A, et al. Energy and economic efficiency performance assessment of a 28 kWp photovoltaic grid-connected system under desertic weather conditions in Algerian Sahara. Renew Energy 2019. doi:10.1016/j.renene.2019.05.086..

[9] A. Hemza, H. Abdeslam, C. Rachid, and N. Aoun, “Simplified methods for evaluating the degradation of photovoltaic module and modeling considering partial shading,” *Measurement*, vol. 138, pp. 217–224, 2019.

[10] N. Kahoul, R. Chenni, H. Cheghib, and S. Mekhilef, “Evaluating the reliability of crystalline silicon photovoltaic modules in harsh environment,” *Renew. Energy*, vol. 109, pp. 66–72, 2017.

[11] A. Bouraiou *et al.*, “Experimental investigation of observed defects in crystalline silicon PV modules under outdoor hot dry climatic conditions in Algeria,” *Sol. Energy*, vol. 159, no. December 2017, pp. 475–487, 2018.

[12] Blal M, Khelifi S, Dabou R, Sahouane N, Slimani A, Rouabhia A, et al. A prediction models for estimating global solar radiation and evaluation meteorological effect on solar radiation potential under several weather conditions at the surface of Adrar environment. Measurement 2020;152:107348. doi:10.1016/J.MEASUREMENT.2019.107348.