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Experimental study of the photovoltaic module deterioration in the extreme weather desert environment of Adrar

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Abstract

The degradation of the electrical performance of photovoltaic panels UDTS 50W 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 UDTS 50W photovoltaic panels tested in the real conditions of the Saharan environment (Adrar region). The degradation of the electrical performance of the UDTS-50 W 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 IV and PV of the PV modules (UDTS 50) 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.

Keywords: Degradation; Photovoltaic panels; UDTS-50W; electrical performance.

1. 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. Solar cells can power systems with power levels ranging from a few milliwatts to megawatts. They are reliable, static and do not require maintenance [4].[2],[3],[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 UDTS-50. 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 (UDTS 50) and the reference in STC illustrated a degradation on the electrical performances (Icc, 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.

2. Model of I-V characteristic of a photovoltaic module

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] [7]:

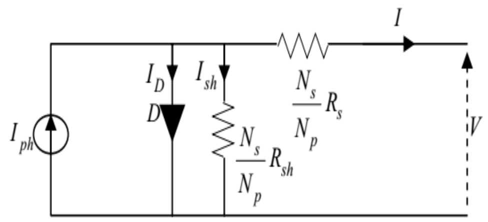

Fig. 1. Equivalent circuit of a photovoltaic generator [8] [9]

After circuit analysis, the voltage current equation is given as follows [9][10]:

$$I = I_{pv} - I_0\left[\exp\left(\frac{V + I R_s}{A V_T}\right) - 1\right] - \frac{V + IR_s}{R_p} \qquad (1)$$

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), Ns: Number of modules connected in series in a branch,Np: Number of branches. 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 UDTS 50W model physical parameters such that the I-V curve obtained by the simulation corresponds exactly to the experimental curve [11].

Fig. 2 represents a comparison between the experimental curve and UDTS-50 PV module simulation based on experimental input data (T = 40°C et G=900 w/m²).It is observed that the experimental and simulated results are precisely matched in three key points: Short-circuit I_{CC}, the open-circuit voltage V_{OC} and the maximum power P_{max} .

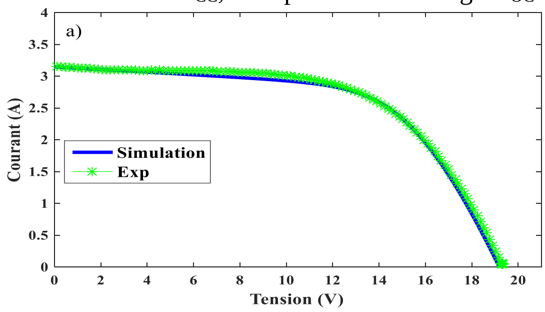

Fig.2. UDTS-50 PV module experimental and theoretical I - V characteristics.

3. Experimental section

3.1 Experimental testing platform description

All experimental tests were carried out in the Renewable Energy Research Unit (URERMS) Adrar. We chose to work on three UDTS 50W 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 UDTS-50W 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 Fig. 3.

Fig. 3. Measurement platform

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.

3.2 PV UDTS-50W 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 (Fig. 4) and the electrical performances degradation of the three PV panels UDTS50W which are exposed to the sun for a long time at URERMS-Adrar.

Fig. 4. Different modules UDTS-50W are tested: Module (A) in the left (Discoloration EVA), Module (B) in the medium (accumulation of sand on the solar panel), Module (C) in the right (Hot spot on the cells)

3.3 I-V and P-V characteristics results of the UDTS 50 module

To evaluate the UDTS-50 W 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) and module B (sand accumulation), module C (dark EVA discoloration).

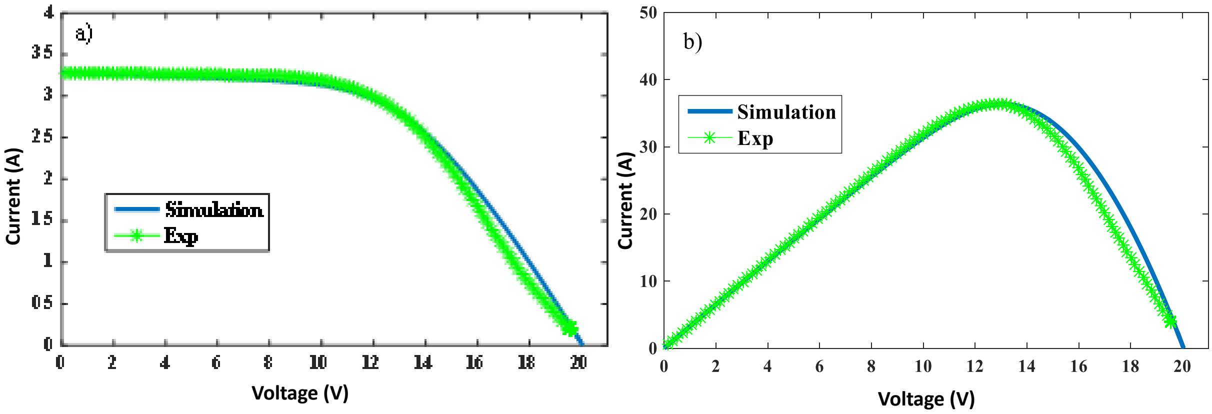

Fig. 5. Comparison between the experimental of UDTS 50 W model (A) and simulation in STC, a) I-V characteristic curves, b) P-V characteristic curves

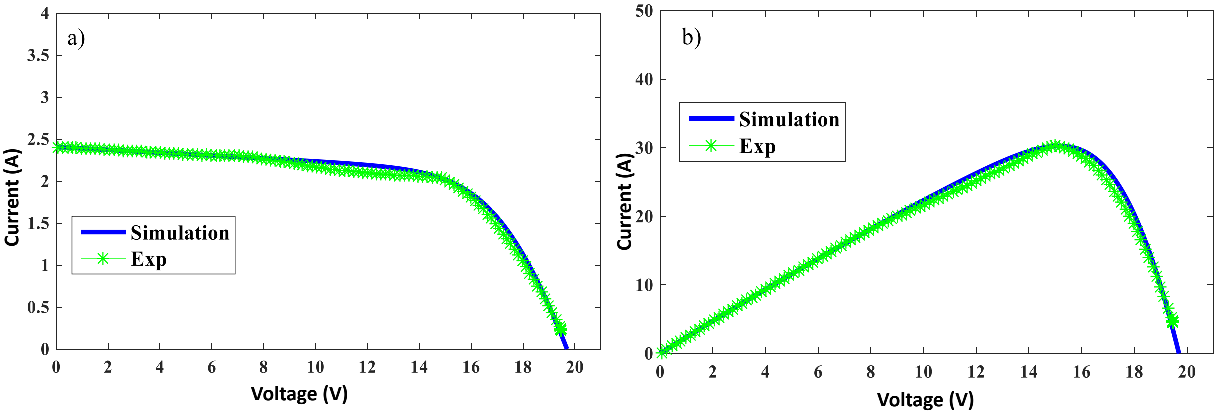

Fig. 6. Comparison between the experimental of UDTS 50 W model (B) and simulation in STC, a) I-V characteristic curves, b) P-V characteristic curves

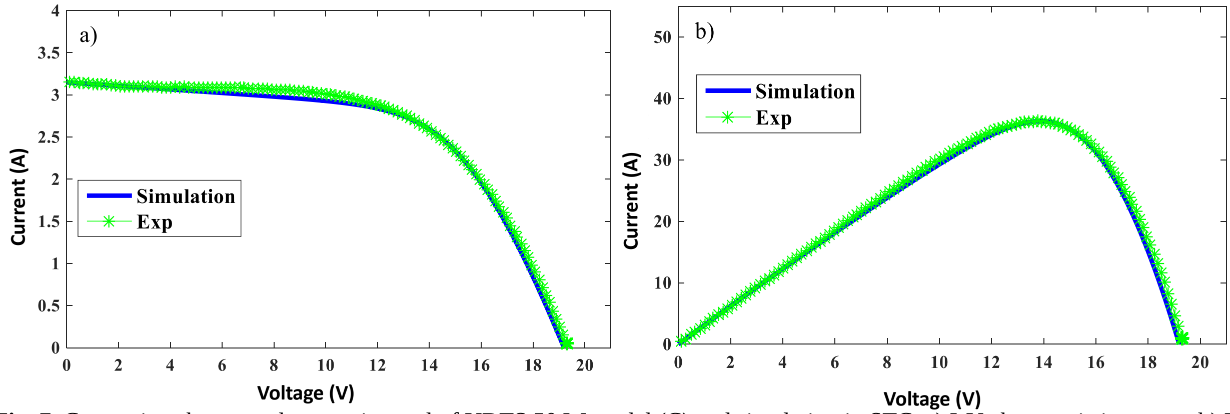

Fig. 7. Comparison between the experimental of UDTS 50 W model (C) and simulation in STC, a) I-V characteristic curves, b) P-V characteristic curves

Fig. 5, 6, 7 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 Icc,, the open circuit Voltage Voc, the maximum power Pmax. 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.

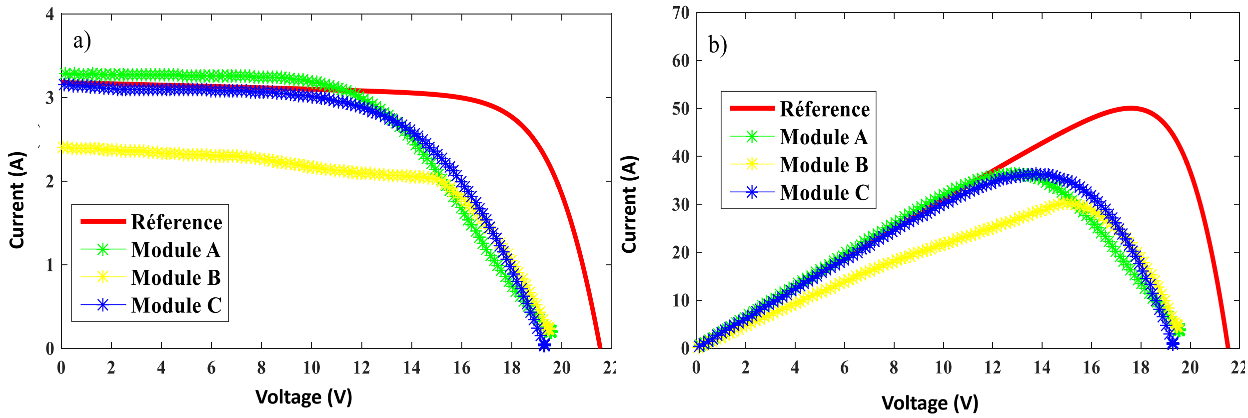

Fig. 8. Comparison between the experimental of UDTS 50 W model and the reference in STC, a) I-V characteristic curves, b) P-V characteristic curves

Fig. 8, represents a comparison between the experimental results of the UDTS-50 W modules and the reference. It is observed that the electrical performance of the UDTS-50W 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), the sand accumulation on the solar panel for the PV module (B) and the hot spot on the cells for the PV module (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 UDTS 50 W modules performance parameters tested

Parameters	Reference module	Module A	Module B	Module C
Maximum power P_{max} [W]	50	36.328	30.253	36.285
Optimum current I_{opt} [A]	2.9	2.806	2.012	2.634
Optimum voltage V_{opt} [V]	17.5	12.945	15.040	13.774
Short circuit current I_{cc} [A]	3.18	3.279	2.405	3.147
Voltage in open circuit V_{oc} [V]	21.6	20.106	19.860	19.375
Form factor FF [%]	0.738	0.551	0.633	0.595
Ideality factor of the junction A	1.3	1.3	1.3	1.3
Resistance series of module R_s [Ω]	0.2300	1.5900	0.7000	0.9200
Shunt resistance of module R_{sh} [Ω]	124.6945	94.9589	58.4270	47.1716

4. Conclusion

The main purpose of this work is to study the degradation of UDTS-50W 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 (I_{cc} ,V_{oc}, P_{max}, 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 encapsulate under the effect of UV irradiation and high temperature the accumulation of sand on the solar panel under the effect of wind or rain.
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 (UDTS-50W) 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.

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