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Performance Evaluation of Photovoltaic Modules in Saharan Environment

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Abstract— **This paper presents an evaluation of the performance of Photovoltaics modules (UDTS 50) after a period of exposition under a desert environment in south of Algeria. This approach based on determining the degradation factor, the different performances parameters of tested photovoltaic modules (P_{max},V_{max},I_{max},V_{oc},I_{sc},R_s,R_p,FF,η) under the standard test condition (STC) with the references parameters (P_{max0},V_{max0},I_{max0},V_{oc0},I_{sc},R_{s0},R_{p0},FF_0,η_0) are used to calculate the degradation rate, the I-V and P-V Characteristics of the tested Photovoltaic modules (PV_{m1}, PV_{m2}) are compared with the reference(PV_{ref}) I-V and P-V Characteristics under STC condition are presented in this work.**

Keywords— **Photovoltaic module; Performance ; Desert environment;STC**

I. INTRODUCTION

Photovoltaic solar energy is the direct conversion of part of the solar radiation into electrical energy. This energy conversion is carried out through a so-called photovoltaic (PV) cell [1] based on a physical phenomenon known as the photovoltaic effect of producing an electromotive force when the surface of the cell is exposed to light. The combination of several PV cells in series/parallel give a photovoltaic generator which has a current-voltage characteristic (I-V) non-linear with a maximum power point. The photovoltaic module performance and its degradation depend on the weather conditions [2,3,4] such as irradiation and temperature, wind, humidity. this paper divided into two sections, the first allowed to give the modeling of photovoltaic module based on one diode model and the description of the degradation factor that used for evaluate the PV performance, the second is the application of this approach for the assessment procedure.

II. MODELLING OF PHOTOVOLTAIC MODULE

A. The single diode model

The following figure presents the single diode electric model of the photovoltaic module [5]

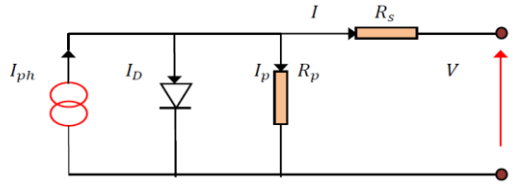

Fig . 1 Equivalent electrical Circuit of one diode model

$$I = I_{Ph} + I_0(\exp(\frac{V + IR_s}{aV_T}) - 1) - \frac{V + IR_s}{R_p} \quad (1)$$

Where I and V is the output current and voltage of the photovoltaic module and I_o is the reverse saturation current of diode, a is the diode ideality factor.

The photocurrent is given by

$$I_{Ph} = (I_{Ph.STC} + K_I.\Delta T).\frac{G}{G_{STC}} \quad (2)$$

Where the $I_{ph,STC}$ is the photocurrent under standard test Conditions (STC] , $\Delta T=T-T_{STC}$ (T=25°C),G is the actual Irradiation and G_{STC} (1000W/m^2),K_I the short-circuit current/temperature coefficient.

$$I_0 = \frac{I_{sc,STC} + K_I \Delta T}{\exp[(V_{oc,STC} + K_V \Delta T)/aV_T] - 1} \quad (3)$$

(3)

K_V is the open-circuit voltage/temperature coefficient, $I_{sc,STC}$ is short circuit current and $V_{oc,STC}$ is open circuit voltage at STC condition. V_T is the thermal voltage.

$$V_T = \frac{N_s KT}{q} \quad (4)$$

B. Determination of the photovoltaic module parameters

In this work the R_s and R_p are obtained through iteration method proposed in [6].the flowchart presented as below(figure 2) give the solution for determent the value of dynamic resistances R_p and R_s. The basic idea maximum power point matching, between the experimental data peak power $P_{mp,ex}$ and the calculated $P_{mp,cal}$ peak power by iteratively calculating the R_p value while increasing the value of R_s .

(5)

$$R_P = \frac{V_{mp,ex} + I_{mp,ex}.R_S}{I_{PV} + I_0[\exp(\frac{V_{mp} + R_S I_{mp}}{a.V_T}) - 1] - \frac{P_{max,ex}}{V_{mp,ex}}}$$

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The initial value of R_s and R_p are given below.

$$R_{P,\min} = \frac{V_{mp,ex}}{I_{sc,ex} - I_{mp,ex}} - \frac{V_{oc,ex} - V_{mp,ex}}{I_{mp,ex}} \quad (6)$$

$$R_{s,\min} = 0 \quad (7)$$

The photocurrent is calculated by

$$I_{pv,n} = I_{sc,n} \cdot \frac{R_p + R_s}{R_p} \quad (8)$$

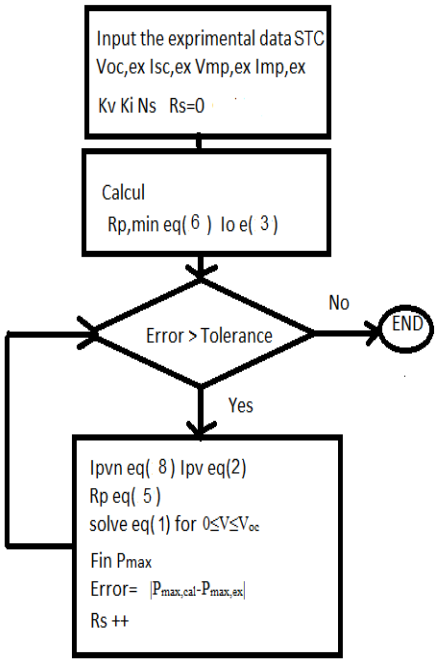


Fig .2 Flowchart of Algorithm

III. Degradation Of A Photovoltaic Module

The photovoltaic module performance and efficiency can be degraded due to several factors: climatic condition (irradiation temperature, humidity), and external cause SUCH as mechanical shock [7].

A. Modes of modules degradation

The table below shows the Failure Modes of photovoltaic module existing in the PV Fields [7,8,9].

TABLE I
DEGRADATION MODES OF PV PANEL

Degradations
Delamination of the encapsulant
Discoloration of the encapsulant
Corrosion
Broken cells
Broken glass
Junction box failures
Broken interconnects
Hotspots
Bypass diode failures

A. Degradation rate (degradation factor)

In order to evaluate the photovoltaic performance modules the degradation factor is used in this work [10,11,12].

$$R_D(\%) = (1 - \frac{Y}{Y_0}).100 \quad (8)$$

Where Y=[P_{max},V_{max},I_{max},V_{oc},I_{sc},R_s,R_p,FF,η] after degradation Y_0=[P_{max0},V_{max0},I_{max0},V_{oc0},I_{sc},R_{s0},R_{p0},FF_0,η_0] the reference values given manufacturers data under standard test condition (STC).

IV. Results and Discussion

A. Experimental Setup

The figure below presents the Hardware and software used in the experiments.

Fig .3 Hardware and software MP-160 of experimental Setup URERMS ADRAR

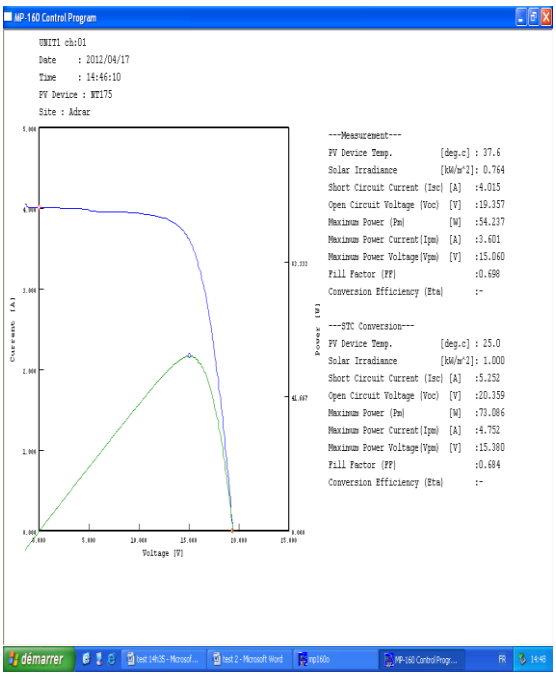


Fig .4 I-V and P-V Tracer

A. *Matlab/simulink model*

The Matlab/Simulink model used for simulation the characteristics I-V and P-V of photovoltaic UDT50 panel is presented by [5,6]:

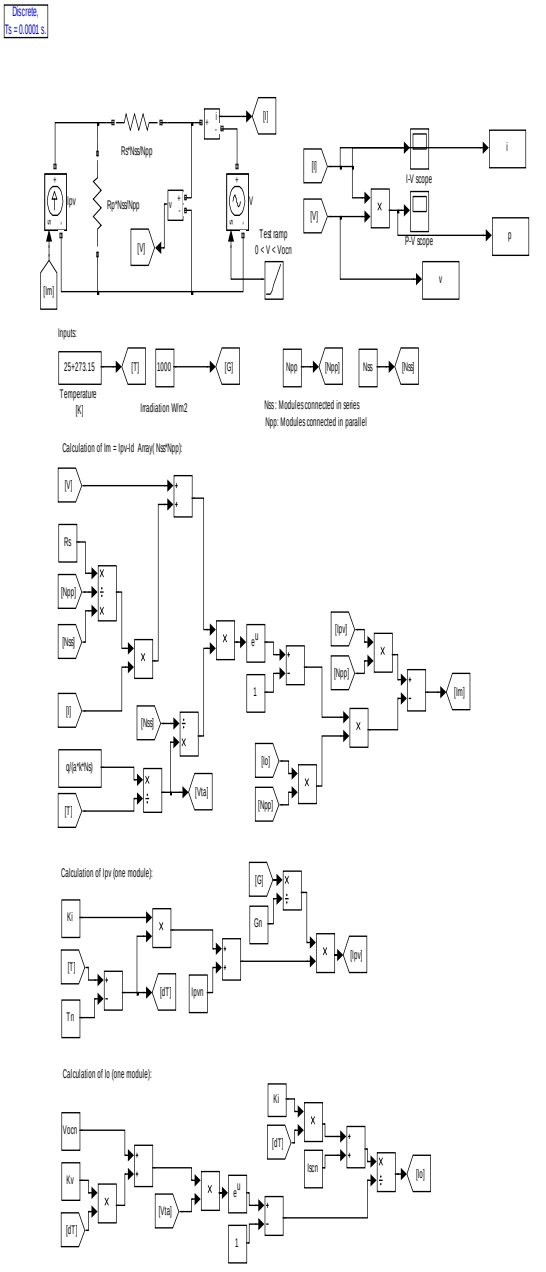


Fig .5 Matlab/Simulik Model used in simulation of photovoltaic panel

B. *The Electricals Parameters of UDTS 50*

The Parameters in STC condition of UDTS 50 Modules are given from data sheet presented in the Table 2 below.

TABLE 2
THE PV MODULE DATASHEET

Parameters	Values
Short-circuit current I_{sc} (A)	3.18
Open-circuit voltage V_{oc} (V)	21.6
Maximum current I_{mp} (A)	2.9
Maximum voltage V_{mp} (V)	17.5
Maximum power P_{max}	49.4
Cells numbers N_s	36
Fill factor FF	72 %
Efficiency η	12.83%

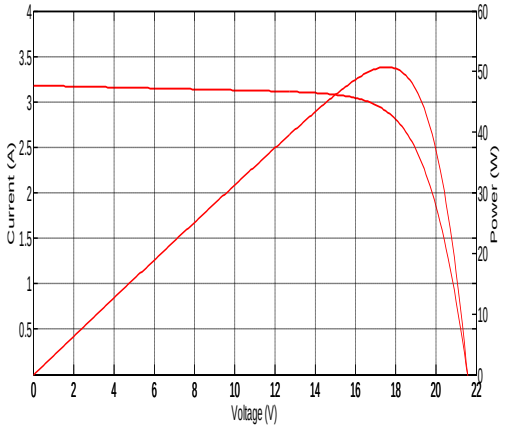
C. *Extraction of the photovoltaic module parameter*

In this part we use the method presented in previous section for determination of PV module parameters (UDTS50). the following table show the parameters of PV module after using the extraction algorithm

TABLE 3
PARAMETERS FOR ONE DIODE MODEL

Parameters	Values
I_{sc} (A)	3.18
V_{oc} (V)	21.6
I_{mp} (A)	2.9
V_{mp} (V)	17.5
I_0 (A)	$5.021x10^{-8}$
I_{pv}(A)	3.184
Shunt R_p (Ω)	198.10
Series R_s (Ω)	0.25

D. *Simulation of I-V and P-V Characteristics under STC*



condition

Fig .6 I-V and P-V curve under STC condition

E. Evaluation performance of PV Module

The table below contain the main parameters of some tested modules (PV_{m1}, PV_{m2}) under STC condition with the parameters of reference module (PV_{ref}) presented section 2 c [13]

TABLE 4
MAIN PARAMETERS OF SOME TEST MODULE COMPARED WITH REFERENCE VALUES (STC DATA)

Parameters	PV_{ref}	PV_{m1}	PV_{m2}
p_{max}	49.4	23.2	44.52
I_{sc} (A)	3.18	2.06	3.20
V_{oc} (V)	21.6	18.83	21.19
I_{mp} (A)	2.9	1.71	2.81
V_{mp} (V)	17.5	13.56	15.82
R_p	198.10	70.11	97.05
R_s	0.25	1.29	0.78
FF %	72	59.9	65.6
η %	12.83	5.47	10.43

Table 5 shows the evaluation of photovoltaic module performance using the degradation factor

TABLE 5
DEGRADATION FACTOR OF SOME MODULE

Parameters	R_{Dm1}	R_{Dm2}
p_{max}	53.04	10.53
ΔI_{sc} (A)	35.22	-0.62
ΔV_{oc} (V)	12.82	1.9
ΔI_{mp} (A)	41.03	3.1
ΔV_{mp} (V)	22.51	9.8
ΔR_p	64.61	51
ΔR_s	-416	-212
ΔFF %	16.8	8.89
Δη %	57.36	18.71

The followings figures present the I-V and P-V curves of the Photovoltaic modules (P_{m1}, P_{m2}) compared with the reference I-V and P-V Characteristics under STC condition.

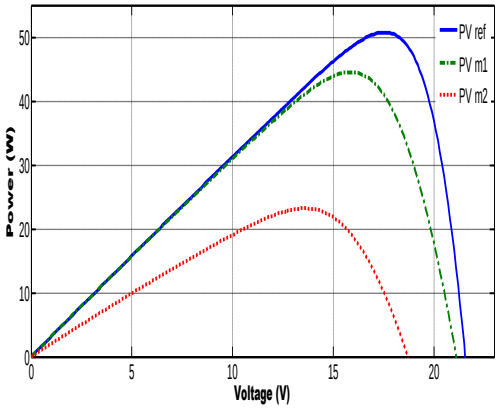


Fig .7 P-V curve of PV_{ref} compared with PV_{m1} and PV_{m2} under STC

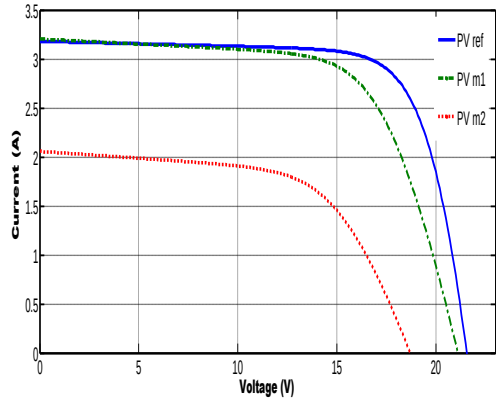


Fig .8 I-V curve of PV_{ref} compared with PV_{m1} and PV_{m2} under STC

From the tables analysis and the figures presented, we can deduce that the power decrease due the degradation of the modules performances caused by the long time of exposition in outdoor weather conditions in desert area.

V. CONCLUSION

In this paper the performance evaluation of photovoltaic module UDTS 50 under the Saharan environment is investigated. The modelling of PV panel based on one diode model is presented, the analysis of the degradation factor shows the impact of the climatic conditions on the photovoltaics modules performance.

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