Available online at www.scholarsresearchlibrary.com

Scholars Research Library

Archives of Physics Research, 2010: 1 (1) 1-11
(http://scholarsresearchlibrary.com/archive.html)

Characterization and Fine Modeling of Electric Operation of Photovoltaic Panels

T. Mrabti[1], M. El Ouariachi[1], Ka. Kassmi[1], K. Kassmi[1*], B. Tidhaf[2]

[1]*Université Mohamed Premier, Faculté des Sciences, Laboratoire LEPAS, Oujda, Morocco*
[2] *Université Mohamed Premier, ENSAO, Oujda, Morocco*

Abstract

In this paper, we have presented the results of the characterization and the fine modeling of the electric characteristics current-voltage and power-voltage of the photovoltaic (PV) panels. We have analyzed the electric parameters of PV cells and the optimal electric quantities of PV panels (voltage and power) as a function of the meteorological variations (Temperature, solar irradiation). The obtained results show that the diode parameters of the PV cells depend on solar irradiation. This induces a decrease of the optimal voltage with solar irradiation: when the solar irradiation varies from 300 W/m^2 to 900 W/m^2, the optimal voltage decreases by 11 %. These results are confirmed by the measures of the manual regulation of the maximum power point (MPP) during one day. By taking into account all the modeling results, we have analyzed the electric behavior of the association of the panels in parallels and in series, as well as the ageing of a PV panel. We have shown that the connection of the PV panels in series (parallels) improves (degrade) the optimal performances of the panel, and a panel undergoes an ageing from 4 to 5 W by year.

Keywords: Cells and Photovoltaic panels, electric characterization, fine modeling of the electric characteristics, Pspice simulator, maximum power point (PPM), ageing of the panel.

Introduction

In the field of photovoltaic (PV) energies the fine modeling of the electric operation of the PV panels is essential [1-4]. This will enable on one hand to qualify the technological process of realization of PV cells, and on the other hand to analyze optimal operation as well as the ageing of PV panels. This last study is necessary in order to conceive and to realize adequate PV systems allowing the continuation of the Maximum Power Point (MPP) [4-11].

In the literature few results relate to the characterization and fine modelling of the optimal electric quantities (voltage, current and power) of PV panels as a function of the meteorological conditions (solar radiation, temperature,…) . Generally, one finds a disagreement between the authors who use different cells and photovoltaic panels. D. Shmilovitz [12] considered, for a given temperature that the optimal voltage increases with solar radiation. In an another work, B. J Huang et al [13], showed on modules PV of the type MSX60, for a given temperature, a behaviour of the optimal voltage which depends on solar radiation: when solar radiation is lower (superior) than 150 W/m^2 the optimal voltage increases (decreases) with solar radiation.

In order to clear up the behaviour of the optimal electric quantities of modules PV as a function of the solar radiation, we propose in this work to characterize modules PV of the type SP75 (monocrystalline silicon) and to model in a fine way in the Ppsice simulator the behaviour of the optimal electric quantities as a function of the solar radiation. More particularly we study the electric model, the MPP and the ageing of PV panels.

Results and Discussion

II.1. Symbolization of PV cell

We have symbolized in Pspice the electric diagram of the PV generator formed of 36 cells in series (Figure 1). As shown in the figure 1, a PV cell is formed by the current generator (I_{CC}), the diode (D), the shunt resistance (R_{Sh}), and series resistance (R_S). The current of the diode depends on the technological parameters (dimensions of the PN junction, doping, mobilities of the carriers…) and of the (T) temperature according to the expression:

$$I_D = I_S(T) \bullet \exp\left(-\frac{q \bullet V_D}{K_B \bullet T}\right) \quad -1-$$

Where:
$I_S(T)$: Saturation current,
V_D: voltage at diode terminals,
q: charge of the free electron,
K_B: Boltzmann constant.

From the comparison of the results of simulations to those provided by the manufacturer, we have deduced the various parameters of the diode and PV cell (R_S and R_{Sh}), and dependence of the short-circuit current (I_{CC}) with solar radiation (Le (W/m^2)).

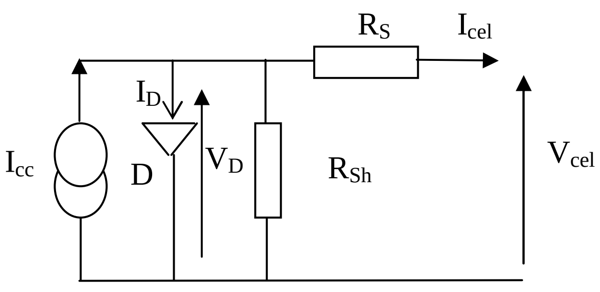

Figure 1: Electric diagram of a Photovoltaic cell.

II.2. Electric characterizations and modeling of PV panels

II.2.1. Experimental procedures

The PV panels (or modules) which were the subject of our experimental study are shown in figure 2. A panel consists of 36 cells monocrystalline, and can provide under the standard conditions of test (solar radiation of 1000 W/m^2, temperature of 25°C, spectrum AM1.5) a power of 75 W and a current of 4.41 under voltage of 17.2 V. These panels and conceived PV systems are characterized from the measuring equipments set up at the laboratory (Figure 3).

Figure 2: Photovoltaic panels SP75 installed at the Faculty of Science of Oujda.

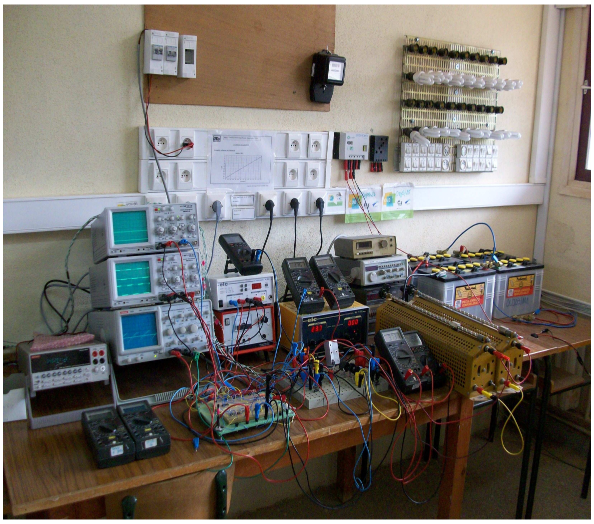

Figure 3: Measuring equipments set up to characterize the photovoltaic panels and systems.

II.2.2. Characterizations and electric modeling of the modules

We have characterized the module during one day when the intensity of solar radiation varies from 300 W/m^2 to 900 W/m^2 and the temperature is around of 22°C - 25°C. On figure 4 we have represented the typical characteristics voltages-current and power-voltage obtained. On the same figures we have represented the characteristics simulated in Pspice by fixing the parameters of the diode (saturations current …) who allows having a good agreement between the experiment and simulation. From the characteristics of figure 4 we have represented on figures 5, the typical variations of the optimal (Vopt) voltage of the panel as a function of solar radiation. It appears that for this temperature 20-25°C the optimal (Vopt) voltage decreases linearly with solar radiation. When solar radiation varies from 300 to 900 W/m^2, the optimal voltage varies from 14.8 V to 13.2 V (a decreasing of 11 %). The comparison between these results with those already published in the literature, show on one hand the values of the cell parameters are different to those fixed by modeling of the characteristics voltage provided by the manufacturer, and on the other hand the strong dependence of these parameters (Vopt…) with solar radiation. The most of works of the literature one supposes that the saturation current of the diode and the Vopt voltage depend very little on solar radiation. By taking account of these assumptions, we have shown in Pspice that when the solar radiation varies from 1.000 W/m^2 to 500 W/m^2 the Vopt voltage undergoes a light decreasing (< to 2%). When the solar radiation is around of 300 W/m^2, this decreasing can reach 5%. In our work and from the modelling of the characteristics voltage-current we have deduced a different behavior: when the solar radiation decreases the

Vopt voltage increases in a considerable way. Consequently, when of the regulation of the power provided by PV panels from MPPT command [2,4-13] , it necessary to take into account of this strong dependence with solar radiation. In order to validate the whole of these results obtained in this paragraph, We have analyzed in the next paragraph, the manual regulation of the power provided by the panel as well as the modelling of the electric performances obtained (Vopt, Iopt, Popt,…) as a function of solar radiation.

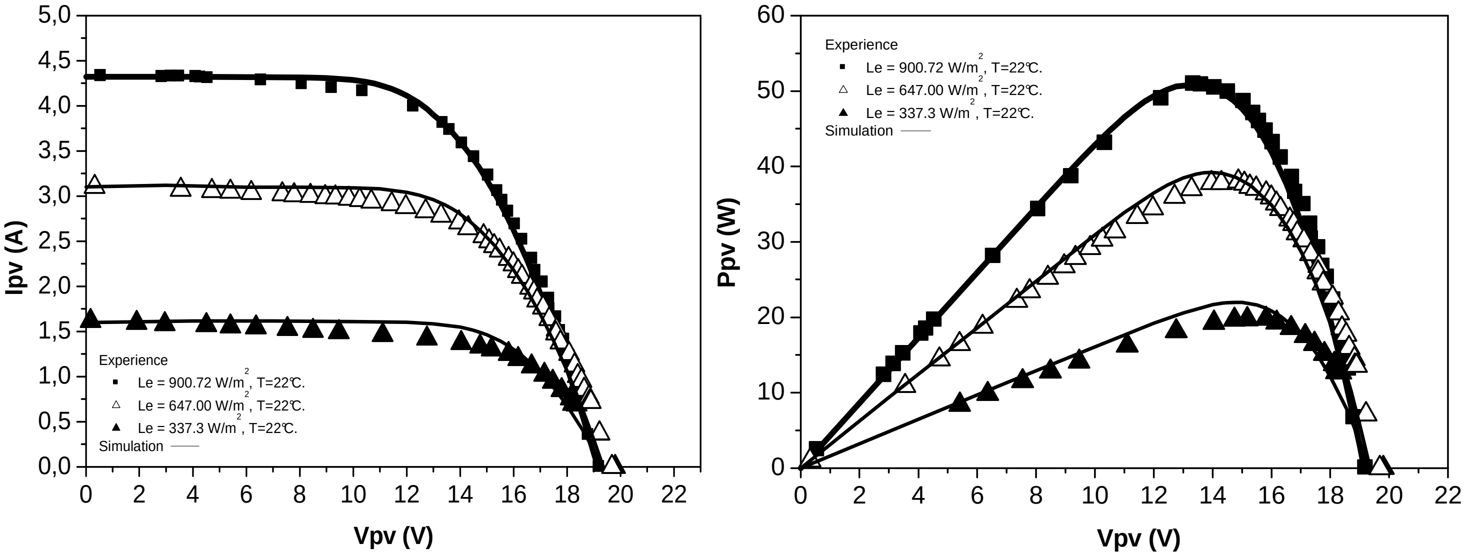

Figure 4: Characteristics current-voltage and power-voltage experimental (■,Δ,□) and simulated in Pspice (——). T: 22-25°C.

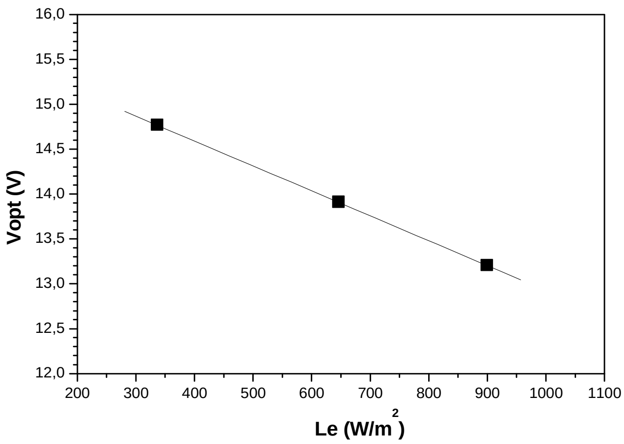

Figure 5: Variation of t the optimal voltage (Vopt) as a function of solar radiation. T: 22-25°C.

II.2.3. Modeling of the regulation of the power provided by PV panels

In order to validate the results obtained in the preceding paragraph, we manually controlled the power provided by PV panel from the system of figure 6. This system is formed by:

- a PV panel,

• A Boost converter dimensioned for that operates at a frequency of 10 Hz [2, 4, 5, 9-11],
• Resistive load of 50 Ω,
• Command formed by an oscillator which generates saw tooth signal of frequency 10 kHz, a comparator and generator of a continuous and variable voltage. The comparison between saw tooth signal and the continuous voltage generates a square signal of variable duty cycle (α).

By varying the duty cycle (α), we have analyzed the regulation of the optimum power provided by the panel during one day when the temperature is of 20°C-25°C and solar radiation varying from 250 W/m^2 to 900 W/m^2. The optimal electric characteristics obtained (Vopt, Iopt and Pot) are shown in figure 7. On the same characteristics, we have deferred the characteristics simulated in Pspice as a function of solar radiation and of the temperature (paragraph II.2.2).

The whole of the results obtained in this paragraph shows that when the temperature varies from 20 to 25 °C the experimental results are very close to those simulated. We notice clearly, the dependence of the Vopt voltage with solar radiation: when solar radiation increases, the Vopt voltage decreases. These results validate those found in the preceding paragraph. Consequently, when the regulation of the operation of PV panels by MPPT command it is necessary to take account of the variation of the optimal voltage Vopt with solar radiation.

To make sure of the good performance of DC/DC converter, we have represented on figure 8, the values of the optimal duty cycle (α_{opt}) of the signal which control the converter switch as a function of solar radiation. On the same curves we represented the values obtained in the Pspice simulator. It appears a good agreement between the experiment and simulation; this shows the good operation of the system of figure 6.

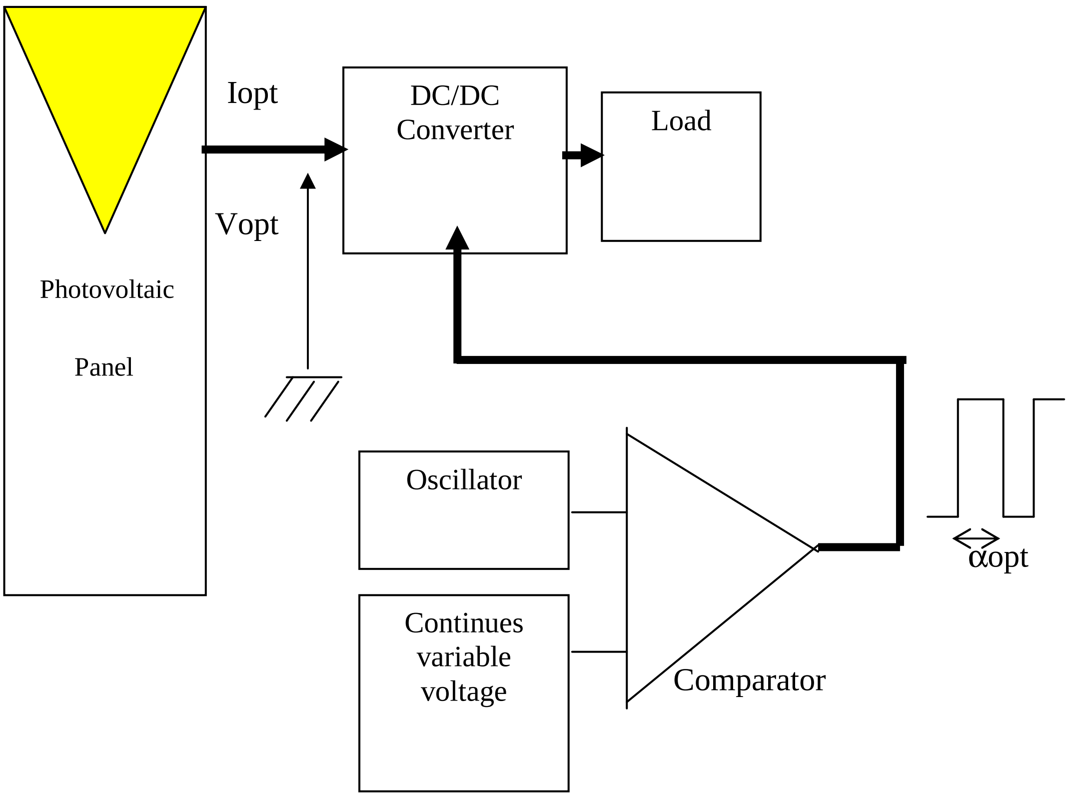

Figure 6: Manual regulation of the power provided by PV panel

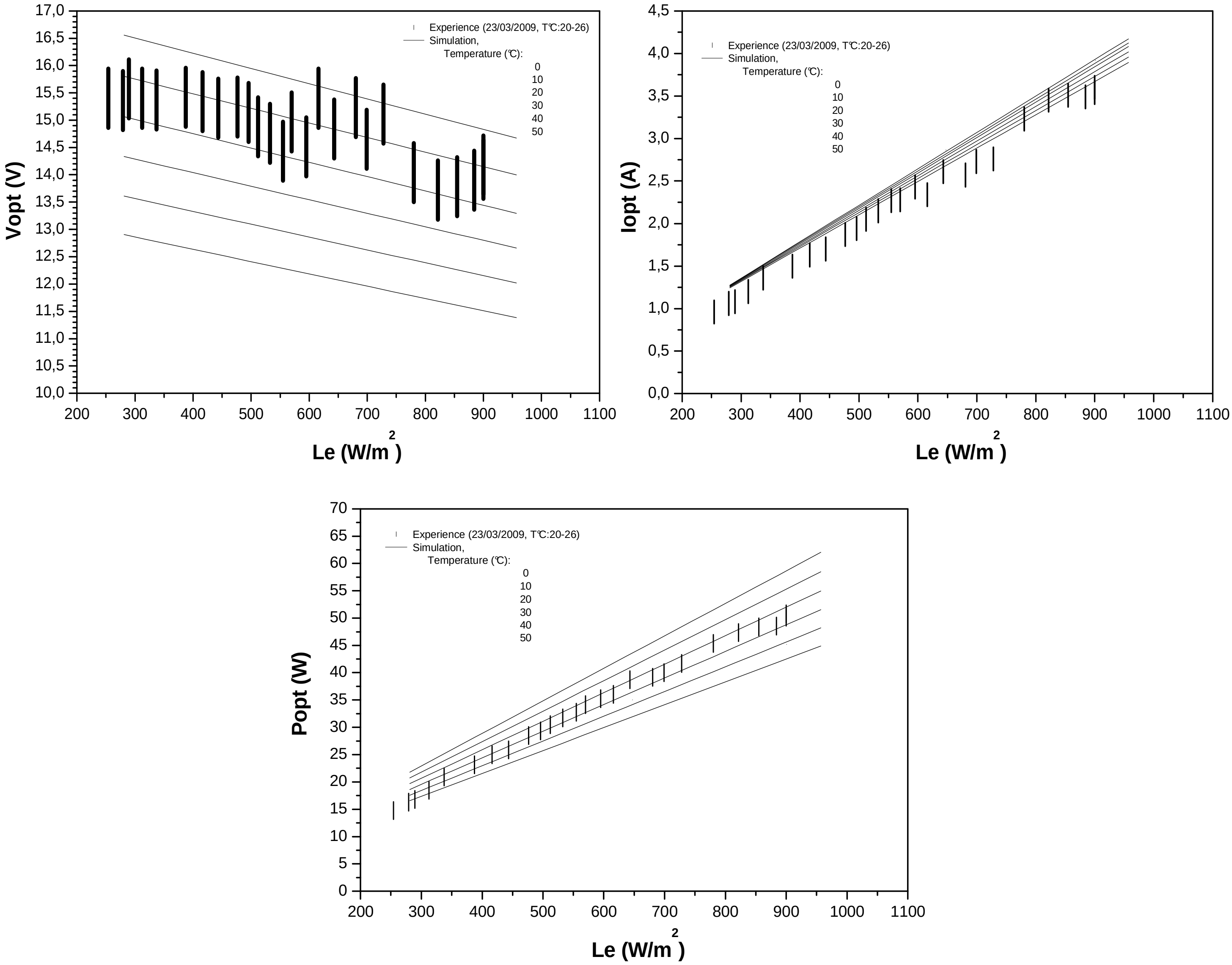

Figure 7*:* Optimal electric quantities (Vop, Iopt and Popt): experimental (│) and simulated in Pspice (——). T: 22-25°C.

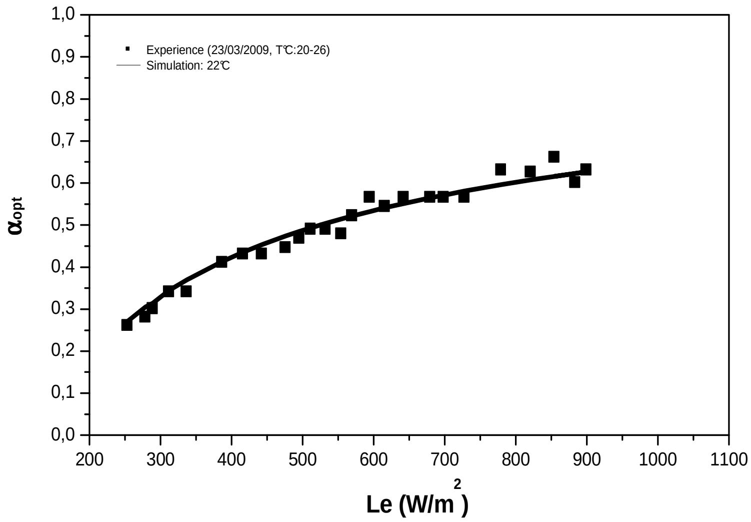

Figure 8: Optimal Duty cycle: experimental (■) and simulated in Pspice (—). T: 22-25°.

II.2.4. Analyzes the operation of the panels in parallel and in series

In a PV installation the panels are associated in parallel and in series. In such an installation in parallel or in series, it is essential to know the optimal behavior of a panel. In our case, we have analyzed the characteristics current-voltage and power-voltage of two or three panels associated either in parallel or in series. The results obtained are represented on figures 9 and 10. It appears that the optimum power is clearly important when the association of the panels in series. When of the associations of two panels in series the improvement can reach 8%.

In order to deduce the behaviour of a panel when of the association of panels in parallel or in series, we have deduced from characteristics 9 and 10 the characteristics current-voltage and power-voltage of one panel (Figures 11 and 12). It appears that short-circuit current (I_{CC}) of a panel is not affected by the association of the panels. As, we have checked as the optimal voltage Vopt of one panel follows the variations analyzed in paragraph II.2.3. From the characteristics of figures 11 and 12, we have deduced and represented on figure 13, the evolution of the relative losses (improvements) of the optimum power of a panel when the association of the panels in parallel (series). It appears that the putting the panels in series, improves the optimal power of a panel, on the other hand the putting in parallel degrades this optimal power in particular when the association of a great number of panels to low solar radiation (< 550 W/m^2).

Since the short-circuit current is not affected by the association of the panels, we have attributed the various behaviors obtained to the leakage current of the diode of PV cells: association in series (parallel) of the PV panels decreases (increases) the leakage current of the diode,

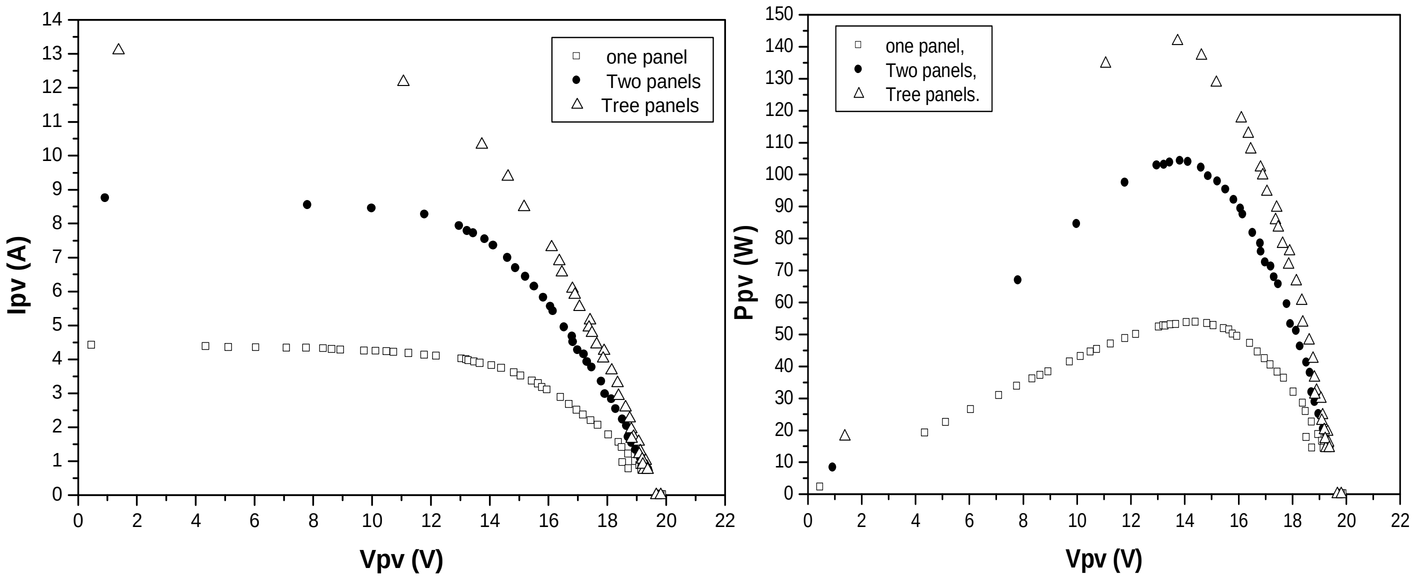

Figure 9: Experimental characteristics current-voltages and power-voltage of a panel, two and three panels assembled in parallel. T: 22-25°C. Solar irradiation = 917 W/m^2.

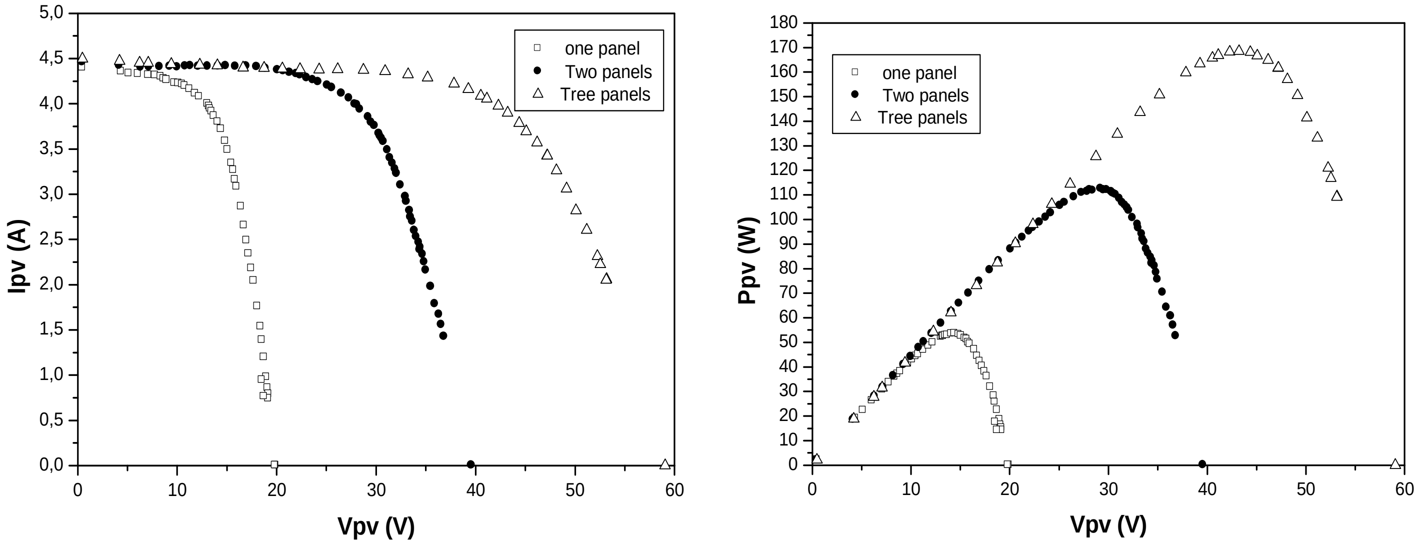

Figure 10: *Experimental characteristics current-voltages and power-voltage of a panel, two and three panels assembled in series. T: 22-25°C. Solar irradiation = 917 W/m^2.*

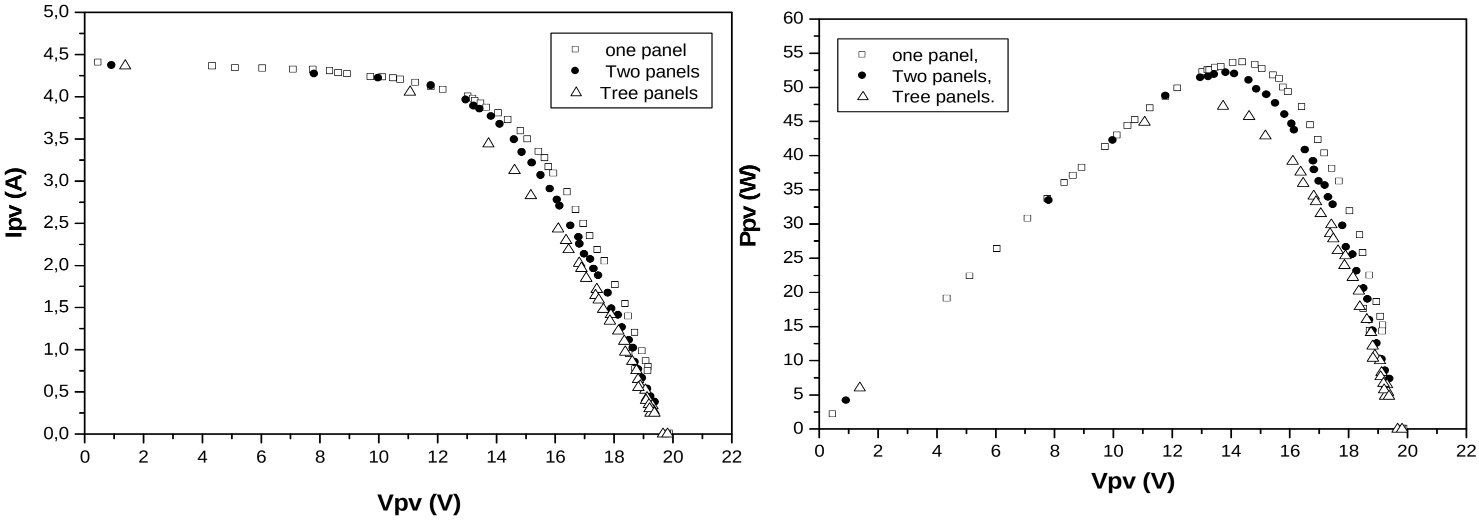

Figure 11: Experimental characteristics current-voltages and power-voltage of a panel, deduced from the characteristics of figure 9. T: 22-25°C, Solar irradiation = 917 W/m^2.

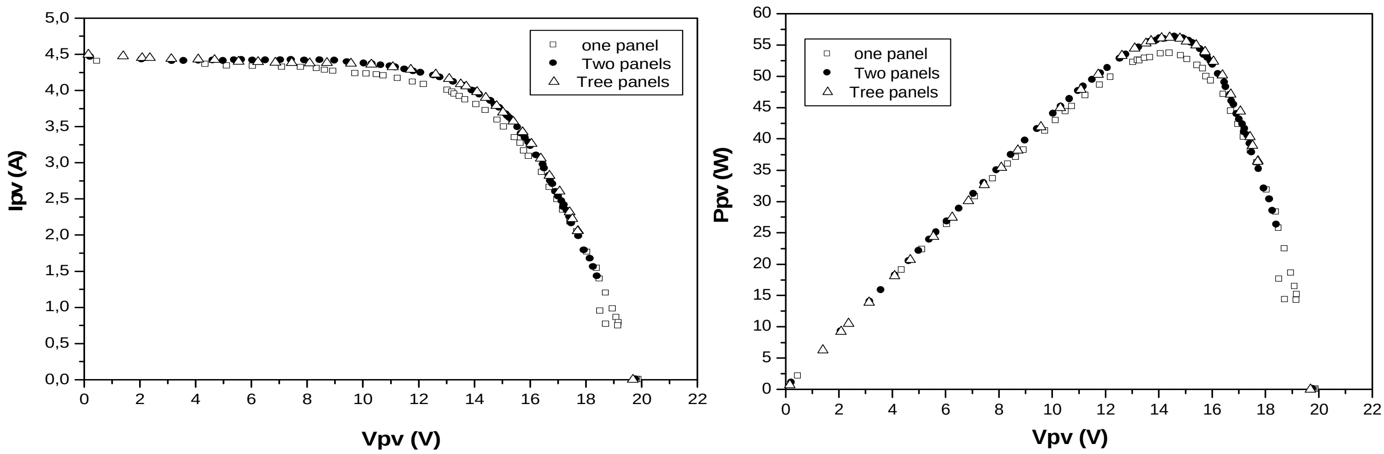

Figure 12: Experimental characteristics current-voltages and power-voltage of a panel, deduced from the characteristics of figure 10. April 1, 2009. T: 22-25°C, Solar irradiation = 917 W/m^2

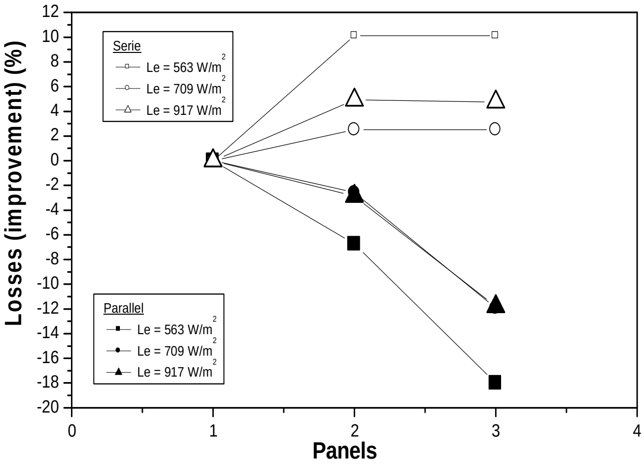

Figure 13: Optimal power losses (improvement) of a panel during the association of the panels in parallel (series) as a function of solar irradiation. T : 22-25°C.

II.3. Ageing of PV modules

The PV panels undergo ageing during their operations. We have analyzed qualitatively the ageing of the panels which were the subject of our studies. We have modelled in Pspice the electric characteristics current- voltage and power-voltage provided by the manufacturer (in 2005) and in particular those of figure 4 (in 2009). On figure 14 we have represented the characteristics simulated and those experimental. We can thus deduce that the experimental characteristics are modelled by different parameters that those obtained when of the modelling of the characteristics provided by the manufacturer. This disagreement could be interpreted in term of the ageing of the panels during their operation. On figure 15, we have represented the degradation of the Vopt voltage, the Iopt current and the Popt power optimal. We can thus conclude that the Popt power is degraded of 25% after five years of function (either 5% or 4 W by year).

Since of the short-circuit current is not degraded after several years of operation of the panels, then as in the case of associations of the panels in parallel or in series, we have attributed qualitatively the ageing of the panels to degradations of the diode of PV cell. The current of these last has the tendency to increase and consequently degrade the electric performances of PV cells.

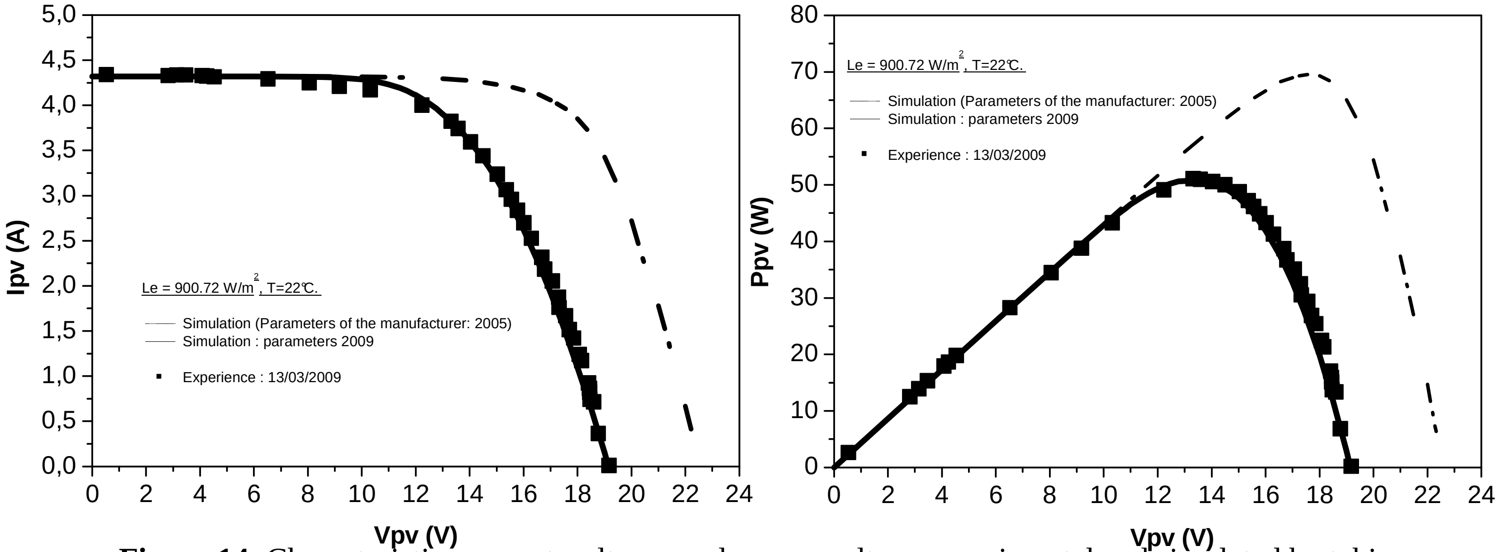

Figure 14: Characteristics current-voltages and power-voltage experimental and simulated by taking into account of the experimental characteristics and those provided by the manufacturer.

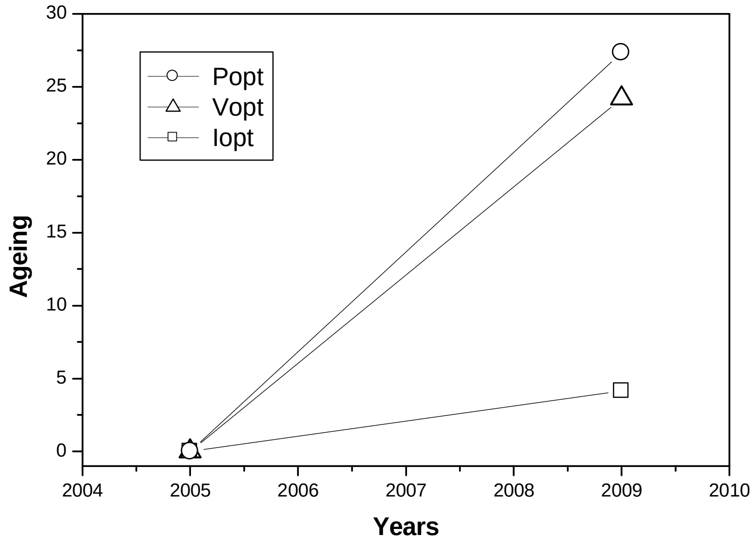

Figure 15: Degradation of the optimal Vopt voltage, Iopt current and Popt power as a function of the years.

Conclusion

In this work we have analyzed in Pspice and characterized the electric operation of the PV panel. The results obtained show that:

• The symbolization of PV panel in Pspice simulator enables to determine the optimal electric operation of PV panel as a function of the meteorological conditions (solar irradiation, temperature…),
• The model of the panels depends on solar irradiation. When the solar radiation varies from 300 W/m^2 to 1000 W/m^2, the optimal Vopt voltage of PV panels varies from 14.8 V to 13 V. These results show well that the decreasing in the optimal voltage with the solar radiation.
• The putting the panels in parallel (series) induced of the losses (improvement) of the performances of the panels. In the case of two panels in parallel (series) the losses (improvement) of the power is around of 3% (5%) for a solar irradiation of 950 W/m^2. These losses and increase are important for weak solar irradiation (300 W/m^2).
• By taking into account of the electric parameters provided by the manufacturer of PV panels, we have deduced ageing the panels of 25% after 5 years of operation (either 4 to 5 W/year).

We have attributed qualitatively the losses and the improvements of the electric power of the panels to the leakages of the diodes of PV cells: the increase (decreasing) in the leakages favours the losses (improvements) electric performances.

Acknowledgments

This work is supported by:
• Programme Thématique d'Appui à la Recherche Scientifique (PROTARS III) 'D43/06,
• Coopération Maroco-Belge « Commission Universitaire Institutionnelle», CUI-Oujda 2008-2012 (Activité Eau et Environnement / sous-activité Energies Renouvelables),

References

[1] Roger Gules, Juliano De Pellegrin Pacheco, Hélio Leães Hey, and Johninson Imhoff, IEEE *Transactions On Industrial Electronics*, VOL. 55, NO. 7, **2008.**
[2] M. El Ouariachi, T. Mrabti, B. Tidhaf, KA. Kassmi, K. Kassmi, *International Journal of Physical Sciences* Vol.4(5) 294 – 309, **2009.**
[3] Achim Woyte, Vu Van Thong, IEEE,Ronnie Belmans, and Johan Nijs, IEEE *Transactions On Energy Conversion*, VOL. 21, NO. 1, **2006.**
[4] Kassmi K., Hamdaoui M et Olivié F., 'Conception, optimisation et réalisation des systèmes photovoltaïques pour une meilleure exploitation de l'énergie solaire', Maîtrise de l'énergie dans la construction et la rénovation des bâtiments Centre d'Etudes Supérieures Industrielles – CESI, 8 novembre **2007** , Rouen, France.
[5] Kassmi K, Hamdaoui M, Olivié F (2007). « Caractérisation des panneaux photovoltaïques, Conception et optimisation d'un système photovoltaïque pour une meilleure exploitation de l'énergie solaire », Energies Renouvelables, Organisation des Nations Unies pour l'Education, la Science et la culture, Bureau de l'UNESCO à Rabat, Bureau Multi pays pour le Maghreb, Les énergies renouvelables au Maroc, Le débat est lancé. ISBN9954_8068_2_2, pp. 87-110,**2007**, Rabat, Morocco.
[6] Mohamed Firas SHRAIF, 'Optimization and measurement of chain of photovoltaic energy transformation into electrical energy', Doctorate of the University Paul Sabatier of Toulouse (France), Année **2002.**
[7] Z.M. Salameh, F. Dagher, W.A. Lynch, *Solar Energy*, Vol. 46, N° 4, pp.279-282, **1991**.
[8] T. Taftcht, K. Agbossou, M.L. Doumbia, A. Chériti: *Renewable Energy* 33 (**2008**) 1508-1516.
[9]T. Mrabti, M. El Ouariachi, K. Kassmi, F. Olivié, F. BAGUI, *Revue des Energies renouvelables*, Vol.11, N°4 (**2008**), 567-575, CDER.
[10]T. Mrabti, M. El Ouariachi, B. Tidhaf, Ka. Kassmi, F. Bagui, K. Kassmi, International Conference on Multimedia Computing and Systems ICMCS'09 April 02-04, **2009** Ouarzazate-MOROCCO, IEEE Catalog Number: CFP09050-CDR, ISBN: 978-1-4244-3757-3, Library of Congress: 2008912122.
[11]M. El Ouariachi, T. Mrabti, B. Tidhaf, Ka. Kassmi, F. Bagui, K. Kassmi, International Conference on Multimedia Computing and Systems, ICMCS'09 April 02-04, **2009** Ouarzazate-MOROCCO, IEEE Catalog Number: CFP09050-CDR, ISBN: 978-1-4244-3757-3, Library of Congress: 2008912122.
[12] D. Shmilovitz, IEE *Proc.-Electr. Power Appl*., 152, No. 2, **2005**.
[13] B.J. Huang, F.S. Sun, R.W. Ho, *Solar Energy* 80 (**2006**) 1003–1020.