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Calculation of the Internal Parameters of a Photovoltaic Panel from the Measured External Parameters

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Abstract

In this study, a more complex modelling, leaving more choice to the user as to the parameters number and the precision degrees is proposed. By experimental measurements carried out on the panels, we will try to establish an electrical model of the cells photovoltaic by determining the various parameters: Saturation currents and diode quality factors, series and parallel resistors. Taking into account the panels heating, using measurements made with natural lighting, we will then finish calculating new parameters, characterizing the thermal losses and wind influence.

Keywords

Photovoltaic, Panels, Parameters, Current, Diode, Resistance, Voltage.

Introduction

Solar photovoltaic energy directly converts light radiation (solar or other) into electricity, using photovoltaic modules composed of solar cells or photovoltaic cells to realize this energy transformation. When designing a photovoltaic system, i.e. measuring the number of modules required meeting energy requirements, it is important to know the precise characteristics of the modules used, as well the meteorological data corresponding to the location of the photovoltaic installation. Similarly, in order to simulate the medium or long-term operation of a module in an approximate way, we must have a model that best reflects reality, that is, taking into account a number of parameters such as It leads to a satisfactory accuracy, for example, it can be accessed on the basis of a relative error in the electricity production less than 10%. Existing simulation software, the reliability of which is difficult to evaluate given the lack of precision in the models they use, often relies on only a limited number of electrical and thermal parameters. This is undoubtedly due to the desire to impose a constraints minimum on the user, who does not always wish to carry out a series of measurements intended to determine these different parameters. The Sandia National Laboratory (Albuquerque, USA) has developed a photovoltaic sensor model, which can both test sensors and estimate their productivities [1, 2]. A model developed by the Energy Center is based on the model with a diode; this model has been validated experimentally by the Center of Energy in Sophia Antipolis [3-6]. The Madison University has developed a model for the programming of a module simulating photovoltaic sensors called 'PHANTASM' chained to the building thermal simulation program 'TRNSYS' [4]. Both models 'Sandia' and 'Cenerg' certainly offer better precision than the 'Madison' model. However, the latter two require either on-site measurements with respect to the 'Sandia' model or measurements in addition to those generally carried out by the manufacturers with regard to the 'Cenerg' model. This disadvantage is incompatible with the practical purpose of our study, namely the development of our intended software. The type of database (data corresponding to the input parameters of the selected model) of such a software must be able to be set up according to the data supplied by the majority of photovoltaic module manufacturers. The model 'Madison' meets this requirement because it proposes a method of calculating the parameters of the model according to the 'data manufacturer'; this is why this model was chosen.

Electrical Model

For the phenomena associated with generation recombination of carriers within the junction, we have a slightly different form, because these phenomena depend on the junction thickness, which itself depends on the junction voltage, so we will have the form:

$$I = I_{02}\left(\exp\left(\frac{q(V-R_S I)}{N_c \gamma_2 K T_c}\right)-1\right)+I_{01}\left(\exp\left(\frac{q(V-R_S I)}{N_c \gamma_1 K T_c}\right)-1\right)+\cdots I_{0n}\left(\exp\left(\frac{q(V-R_S I)}{N_c \gamma_1 K T_c}\right)-1\right)+\frac{(V-R_S I)}{R_{sh}}-I_l \quad (1)$$

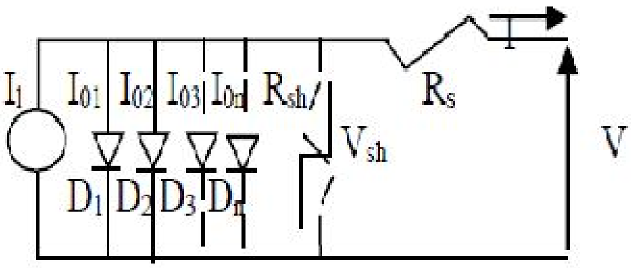

Figure 1: Electrical model

Where, **I** is the current entering the module. The photo current **I**$_l$, which depends on the incident radiation and the cell temperature, who can be determined on the basis of the given value under reference conditions [5-7].

Parameter Determinations

In order to be able to determine the parameters of the model in the most reliable way possible, it is necessary to have a maximum of experimental data (Madisan model) so as to reduce the errors risk. It will be possible to make measurements in darkness or with lighting, with or without heating by Joule effect, in calm or agitated atmosphere, etc…., all this data will be necessary to determine the model in the most complete and precise.

R_{sh} Parameter

Theory: The ideal is to be able to determine each parameter in turn using data that can be interpreted using equations to an unknown, however, by approximation; we can reduce the number of unknowns in an equation [6-8]. Simplifications that we can make concern the operating conditions; it is simpler to place in the laboratory, without wind and rain, and to make measurements fast enough to be able to neglect the heating due to the current and the measurements in dark. In this way, we can consider that the cells temperature is equal to the ambient temperature. In this form of equation, there are 4 unknowns: $\mathbf{I_{D1}}$, $\mathbf{I_{D2}}$, $\mathbf{I_{Rsh}}$, and $\mathbf{I_l}$. This makes us 3 more unknowns, to remedy this; the simplest way is to neglect $\mathbf{I_{D1}}$ and $\mathbf{I_{D2}}$. This choice is to justify the fact that the behavior of an ideal diode, its current takes on a significant value only if the diode voltage is sufficiently high, therefore, if we have low voltage measurements, we can write model:

$$I = \frac{(V - R_s I)}{R_{sh}} - I_l \quad (2)$$

A second choice is to remove the current $\mathbf{I_l}$ in the dark mode from the equation. We will have:

$$I = \frac{(V - R_s I)}{R_{sh}} \quad (3)$$

$\Longrightarrow R_{sh} - R_s = \frac{V}{I}$ As long as: $\mathbf{R_{sh}}$ and greater than $\mathbf{R_s}$ $\Longrightarrow R_{sh} = \frac{V}{I}$

R_s Parameter

Theory: The $\mathbf{R_s}$ calculation method is relatively similar to the following equation.

$$V = \sum V_d + IR_s \quad (4)$$

There are two unknowns for a single equation. Eliminating the unknown $\mathbf{V_d}$ is not very complicated. It is known that when a diode is conductive, its voltage is fixed between 0.5 and 0.7 V and remains almost constant, while the current can undergo strong increases [7]. Consequently, if sufficiently high voltage measurements are available, the voltage $\sum V_d$ can be considered as constant and Rs calculated in terms of slope.

$$R_s = \frac{\Delta V}{\Delta I} \quad (5)$$

I_{0rf} and γ Parameter

We have therefore identified two linear zones ($\mathbf{R_{sh}}$ and $\mathbf{R_s}$). In these zones, the precise value of the current will be determined by the general equation of the current (1), this equation still contains two unknowns which are I0rf and γ. unfortunately, these parameters are difficult to dissociate. That is, we know that γ takes a value between 1 and 5 (the number of cells in series) consequently, it will suffice to arbitrarily set a value to γ and then to calculate $\mathbf{I_{0rf}}$, by successive iterations, we should then arrive at the right value [8-11].

Thermal Model

The behaviour of the cells as a function of temperature variations is given by equation 1 of the model. The cell temperature can be determined experimentally and depends on the incident solar radiation, the ambient temperature, the wind speed and the construction mode of the module [12,13]. It is possible to design a simple thermal module or:

$$\Delta T = \frac{G_i}{K} \quad (6)$$

$$K = h_c + h_v w \quad (7)$$

The heating is due to a power absorption by the cells. However, the radiation represents only the input power and not the power absorbed, so it is necessary to take into account the output power of the module in order to calculate this absorbed power. We must therefore first calculate the power that the module receives by multiplying the incident radiation by the surface Sm of the module. The model then becomes:

$$\Delta T = \frac{S_m G_i - VI}{h_c + h_v w} \quad (8)$$

Determination of Thermal Model Parameters

The first parameter that we can determine experimentally is the factor $\mathbf{h_c}$. Indeed, by creating the darkness around the module in laboratory conditions, then $\mathbf{G_i = 0}$ (solar radiation), **w = 0** (wind speed).
If a constant current is injected into the module for a sufficiently long period, the module gradually heats up to a regime temperature, the temperature rise will then be given by:

$$\Delta T = \frac{-VI}{h_c} \quad (9)$$

Knowing then the current and the voltage, the equation describing the model is used to determine the temperature of the cells.

Wind Influence

The next step is then to determine the value of $\mathbf{h_v}$. For this we can, for example, continue in the dark but this time by subjecting the module to the wind influence of the taking measurements at night.

$$\Delta T = \frac{-VI}{h_c + h_v w} \quad (10)$$

The measured $\Delta\mathbf{T}$ represents the increase in temperature undergone by the cells whereas the $\Delta\mathbf{T}$ at heat represents the same temperature difference in the case where the cells heat up as much as in the laboratory. Consequently, we cannot rely on these measurements to determine the parameters of the thermal model. The only remaining possibility is to use the measures taken during the day, which are sufficiently numerous to be able to lend themselves to a statistical calculation [10]. For this, we start from the equation (8) giving the variation of temperature: The left member, containing no unknowns, is a linear function of the wind speed. It is therefore sufficient to represent it graphically and to perform a linear regression. The coefficients of the equation of the line obtained then give the coefficients $\mathbf{h_c}$ and $\mathbf{h_v}$.

Results

Of the experimental data measured on the panels in the laboratory with or without illumination with or without heating are presented in tables.

Table1: Measurements in darkness for crystalline silicon

V_m(V)	I_m (290 °k)	I_m (295 °k)	I_m (300 °k)
-3	0,000545	0,000535	0,000555
-2	0,00036	0,00036	0,000365
-1	0,00019	0,000175	0,000195
0	0	0	0
1	-0,00019	-0,000175	-0,00017
2	-0,0004	-0,00037	-0,000385
3	-0,00064	-0,0006	-0,00061
5	-0,00116	-0,001055	-0,001105
8	-0,02865	-0,002445	-0,00264
12	-0,0102	-0,00818	-0,00911
15	-0,0352	-0,0253	-0,0299
18	-0,183	-0,124	-0,152
20	-0,642	-0,429	-0,553
21	-1,265	-0,823	-1,05
21.5	-1,61	-1,16	-1,395
22	-2,055	-1,525	-1,84
22.5	-2,64	-1,955	-2,335
23	-3,3	-2,515	-2,99
23.5	-4,06	-3,3	-3,74
24	-5	-3,985	-4,575
24.5	//	-4,945	//

Table 2: Laboratory light measurements for crystalline silicon

V_m(V)	I_m (A)	I_l (A)	T (°k)
1,09	0,00862	0,00888	295
2,81	0,00801	0,00888	295
3,42	0,00788	0,00888	295
4,71	0,00738	0,00888	295
6,32	0,00668	0,00888	295
7,59	0,00606	0,00888	295
8,83	0,00529	0,00888	295
9,71	0,00349	0,00666	295
11,8	0,00228	0,00888	295
12,4	0,00131	0,00975	295
13	0	0,00888	295

Table 3: Measurements with heating

Type	Current (A)	Measured Voltage (V)	Tam (°C)
silicium cristallin	-1	21.6	18.5
	-2	22.5	22.8
	-2.75	22.98	22.8
	-3.5	23.6	22.8

Table 4: Measurements taken at night

Type	Voltage (V)	Tm (°C)	Wind speed (m/s)
silicium cristallin	24.99	7.8	0.9
	24.94	8.1	1.9
	24.84	11.1	0.4
	24.39	15.6	0.5

Using the three curves in crystalline silicon darkness, by repeating the regression many times, find values to which the parameters converge. These values are as follows:

R_p = 4656, R_S = 0.761, Irf1= $1.9528E^{-6}$, γ_1=1.9

I_{rf2} =$1.9001E^{-6}$, γ_2 =1.77

And we obtained, for the crystalline silicon, for the thermal model the following values:

h_c=3.82954 w/°k and h_v=0.17775 W.s / °K.m

The model gives good results in the two linear zones with relative errors not exceeding 10%. The model valid in these two areas, but it behaves very badly in intermediate areas where the error exceeds 25%. The problem is that this area is the most important part in the case where the panel operates under real conditions.

We can say that the model we have defined gives good results, obtained under special conditions (obscurity and rapid lighting), but to validate our models we must subject it to real conditions.

The short circuit current increases linearly as a function of the incident solar radiation. The model gives good results with relative errors not exceeding 10%.

As soon as we expose the cells to the sun and leave them in a state of steady state, the results deteriorate when the sunshine becomes too great. Now, the phenomenon that took place at that time and which can alter (at this point) the behavior of the cells can only be a heating up. To make the simulation efficient, we are therefore obliged to pay more attention to the thermal phenomena that have occurred within the cells.

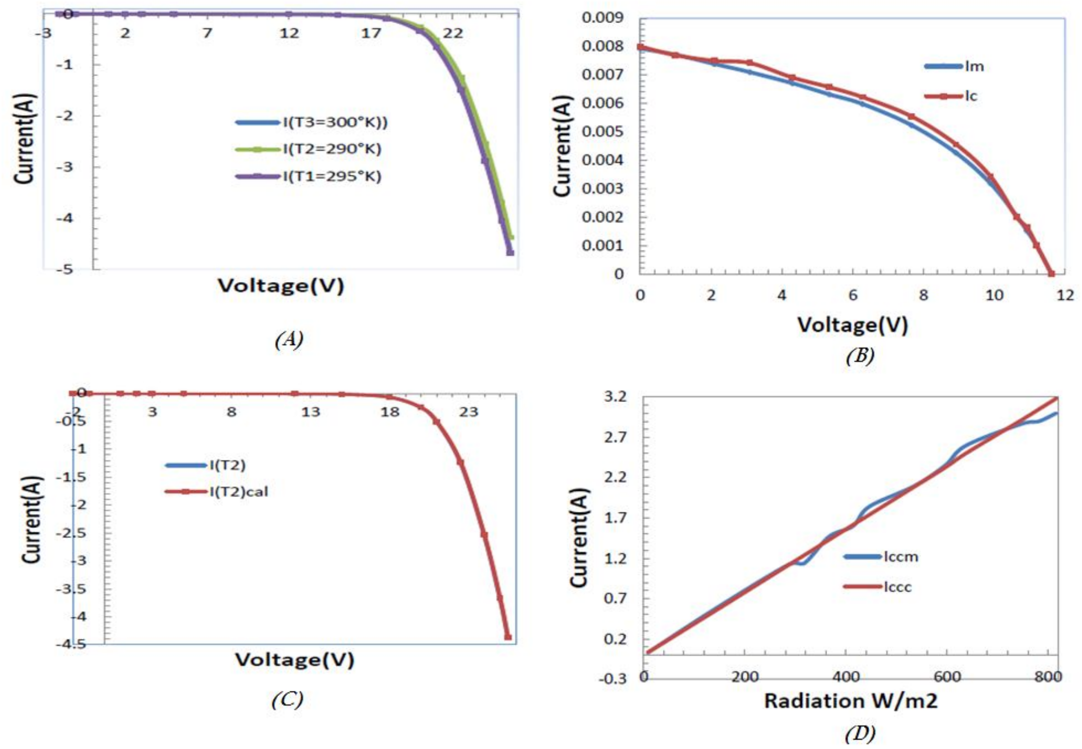

Figure 2: (A) Comparison between the three temperatures measured for crystalline silicon. (B) Comparison between measurements and calculations for crystalline silicon illuminated at a temperature of 295 ° k *(C) and (D)* Détermination graphique du facteur de conversion pour le silicium cristallin

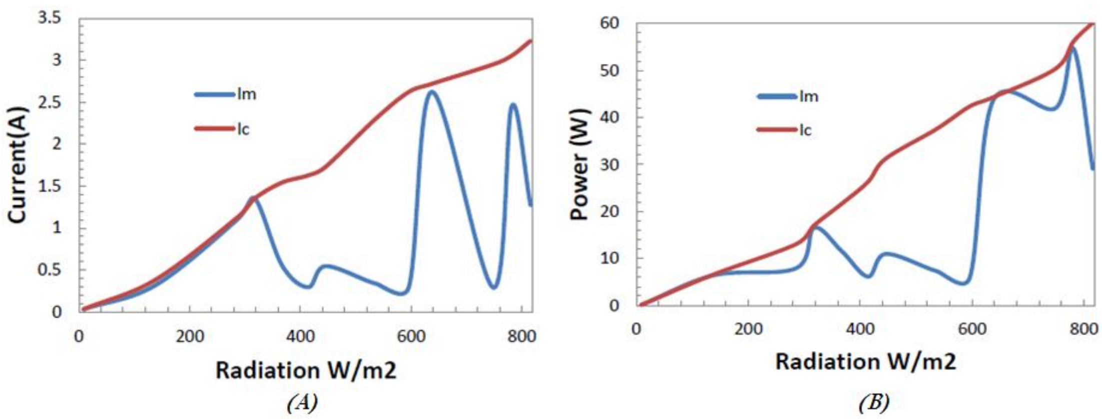

Figure 3: (A) Comparison between the measured and calculated current for real conductive crystalline silicon (B) Comparison between the measured and calculated power for real conductive crystalline silicon

Conclusion

The study of the proposed model was developed from two axes of work: calculation of internal parameters from the data in the dark (electrical modeling), calculates the real temperature of the cells and the thermal behavior. The photovoltaic sensor model is based on the model with diodes of the photovoltaic cell, it applies to most cells made from crystalline or amorphous silicon, which represents the vast majority of cells available on the market. In comparison with the company on the photovoltaic model, it has been observed that the algorithm which makes it possible to calculate the intermediate parameters of the model with a diode according to the data of the constructor does not always converge, and that this depends on Module type. A solution has been proposed to fix parameters in order to solve the convergence problem while adding a second diode to minimize current errors. This diode represents the phenomena related to the diffusion of the carriers, the carriers of the zone of exhaustion, etc. The model was validated experimentally and the results showed that the actual efficiency of the sensor can be 10% lower than that announced by the manufacturers.

Nomenclature

K	Boltzmann constant 1.381.10-23 j/k	Rf	reference
q	Elementary charge 1.602.10-19 c	1	Diode one
I	Current (A)	2	diode two
V	Voltage (V)	S	series
T	Temperature (°K)	Sh	shunt
N	Number	C	Cell, Conduction
R	Resustance (Ω)	L	light
Gi	Radiation (w/m^2)	v	Convection
h	Heat transfer (w/°K m^2)	Greek Symbols	
indice		γ	Adjustenent parameter
0	saturation	εg	Materiel gap, is 1.12 ev for silicom
d	diode	µ	Dependency coefficient

References

[1] King D. L., Kratochvil J. A. and Boyson W. E, 1997. 'Temperature coefficients for PV modules and arrays: measurement methods, difficulties, and results'; 26th IEEE Photovoltaic Specialists Conference, Anaheim, California

[2] Whitaker C. M., Townsend T. U., Newmiller J. D., King D. L., Boyson W. E., Kratochvil J. A., Collier D. E. and Osborn D. E , 1997."Application and Validation of a new PV Performance Characterization Method", 26th IEEE Photovoltaïc Specialists Conference, Anaheim (USA).

[3] Mehmet Yorukoglu, Ali Naci Celik .A, 2006. Critical review on the estimation of daily global solar radiation from sunshine duration. Energy Conversion and Management 47 p 2441–2450

[4] S. Kaplanis, E. Kaplani, 2007.A model to predict expected mean and stochastic hourly global solar radiation I (h; nj) values. Renewable Energy 32. P1414–1425

[5] Kamal Skeiker, 2006. Correlation of global solar radiation with common geographical and meteorological parameters for Damascus province, Syria. Energy Conversion and Management 47 p 331–345

[6] V. Avrutin, N. Izyumskaya, H. Morkoc, 2014. “Amorphous and micromorph Si solar cells: current status and outlook”, Turk Journal of Physics, 38: 526 -542

[7] E. Cuce, P. Cuce, T. Bali, 2013. “An experimental analysis of illumination intensity and temperature dependency of photovoltaic cell parameters”, Applied Energy, 111: 374-382

[8] O. Breitenstein, 2014. An Alternative One-diode Model for Illuminated Solar Cells, Energy Procedia, 55: 30-37

[9] R. Foster, M. Ghassemi, and A. Cota, 2010. “Solar Energy: Renewable Energy and the Environment”, CRC Press Taylor & Francis Group, Boca Raton, Fla, USA.

[10] D. Rodriguez, P. Horley, J. Hernandez, V. Vorobiev, N. Gorley, 2005. Photovoltaic solar cells performance at elevated temperatures”, Solar Energy, 78: 243-250.

[11] E. Skoplaki, A. PalyvosJ, 2009. On the temperature dependence of photovoltaic module electrical performance: a review of efficiency/power correlations”, Solar Energy Materials & Solar cells, 83: 614-24

[12] K. Ishaque, Z. Salam, H. Taheri, A. Shamsudin, 2011. Simple, fast and accurate two-diode model for photovoltaic modules”, Solar Energy, 85: 1768-1779

[13] U. Stutenbaeumer, B. Mesfin, 1999.Equivalent model of monocrystalline, polycrystalline and amorphous silicon solar cells”, Renewable Energy, 18: 501-512

[14] Whitaker C. M., Townsend T. U., Newmiller J. D., King D. L., Boyson W. E., Kratochvil J. A., Collier D. E. and Osborn D. E , 1997."Application and Validation of a new PV Performance Characterization Method", 26th IEEE Photovoltaïc Specialists Conference, Anaheim (USA).