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Photovoltaic Panels Characteristics Methods

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***Abstract*—The power provided by the PV array varies with solar radiation and temperature, since these parameters influence the electrical characteristics of solar panels. In Scientific researches, there are different methods to obtain these characteristics. In this paper, we present three methods. The first one is the simulation method by using Matlab/Simulink. The second one is the classical experimental method with a variable resistive load and the third one used a system acquisition (card NI PCI 6259 and LabView™ software). The obtained results in each case and under different meteorological conditions are presented.**

***Keywords*— Panels, Photovoltaic, Characteristics, Labview.**

I. INTRODUCTION

Renewable energies constitute an alternative to conventional energies and their problems are the pollution and CO_2 emissions that they produce the diminution of reserves and their increasing prices. Alternatively, the renewable energy sources like solar energy are clean and abundantly available in nature. Electrical characteristics of photovoltaic cells are influenced by metrological conditions (solar radiation and temperature). Different methods are used to determine these characteristics [1-5]. In this paper, we present three methods. The first one is made using Matlab/simuling. Several mathematical models describe the operation and behavior of the photovoltaic generator[1] and they differ in the calculation procedure, accuracy and the number of parameters involved in the calculation of the current-voltage characteristic. The second one is the classical experimental method with a variable resistive load [5]. The third method is a measurement one for the evolution of the electrical characteristic curves of photovoltaic panels. We use LabView™ software. The developed system enables us to obtain the suitable operation of a PV generator in real time. Electrical characteristics are obtained by using a PV panel and under different solar radiations and temperatures in the region of Bejaia (Algeria).

II. STUDIED PHOTOVOLTAIC SYSTEM

To use the third method which allows us to obtain electrical characteristics, we use PV solar of $80W_c$ (Fig.1.). Its parameters are listed in Table 1.

TABLE 1
PV SOLAR SUNTECH STPO80S-12/BB PARAMETERS

Parameters	Values
Maximum Power at STC P_{PV}	80Wp
Optimum operating current I_{mpp}	4.58 A
V_{mpp}	35V
Short-circuit I_{sc}	4.95A
Open circuit V_{oc}	21.9 V
α_{sc}	3.00mA/°C
β_{oc}	-150.00 mV/°C

Fig.1 Photovoltaic solar SUNTECH STPO80S-12/Bb of 80Wc.

III. MATHEMATICAL MODEL USING MATLAB/SIMULINK

A. *Photovoltaic Panel modelling*

In literature, there are several mathematical models that describe the operation and behavior of the photovoltaic generator [1-3].

1) *One diode model*

The model is called a diode and its equivalent circuit consists of a single diode for the phenomena of cell polarization and two resistors (series and shunt) for the losses (Fig. 2.).

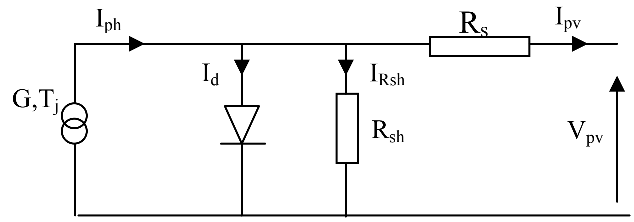

Fig.2.Simplified equivalent circuit of solar cell

$I_{pv}(V_{pv})$ characteristic of this model is given by the following equation [5]:

$$I_{pv} = I_{ph} - I_d - I_{Rsh} \tag{2}$$

$$I_{pv} = I_{ph} - I_0\left[\exp\left(\frac{q.(V_{pv} + I_{pv}.R_s)}{AN_s kT_j}\right) - 1\right] - \frac{V_{pv} + R_s.I_{pv}}{R_{sh}} \tag{3}$$

The different mathematical models generally include parameters that are provided by photovoltaic modules manufacturers. For this, several methods have been proposed in the literature to determine different parameters. In our paper, we use the following approach.

The photocurrent, I_{ph}, is directly dependent upon both insolation and panel temperature, and may be written in the following form:

$$I_{ph} = P_1.G.[1+P_2.(G-G_{ref})+P_3.(T_j-T_{ref})] \tag{4}$$

Where*:* G insolation in the panel plane (W/m²); G_{ref} corresponds to the reference insolation of 1000 W/m² and T_{jref} to the reference panel temperature of 25°C. P_1, P_2 and P_3 are constant parameters.

The polarization current I_d of junction PN, is given by the expression:

$$I_d = I_0.[\exp(\frac{q.(V_{pv}+R_s.I_{pv})}{A.n_s.k.T_j})-1] \tag{5}$$

$$I_0 = P_4 \cdot T_j^3 \cdot \exp\left(-\frac{E_g}{K \cdot T_j}\right) \tag{6}$$

With: I_0 (A) saturation current, q the elementary charge (ev), k Botzman's constant, A ideality factor of the junction, T_j: junction temperature of the panels (°K) and R_s, R_{sh} (Ω) resistors (series and shunt).

The current shunt is given by:

$$I_{sh} = \frac{(V_{pv} + R_s \cdot I_{pv})}{R_{sh}} \tag{7}$$

Thus [1]:

$$I_{pv} = P_1 \cdot E_s \cdot [1 + P_2 \cdot (E_s - E_{ref}) + P_3 \cdot (T_j - T_{ref})] - P_4 \cdot T_j^3 \cdot \exp\left(-\frac{E_g}{K \cdot T_j}\right) \cdot \left[\exp\left(q \cdot \frac{(V_{pv} + R_s \cdot I_{pv})}{A \cdot n_s \cdot K \cdot T_j}\right) - 1\right] - \frac{(V_{pv} + R_s \cdot I_{pv})}{R_{sh}} \tag{8}$$

We determine the seven constant parameters P_1, P_2, P_3, P_4, the coefficient A and the resistance R_s and R_{sh} of PV model with a numerical resolution and the use of the PV panels data sheets. We determine the system of nonlinear equation as follows [5]:

$$\begin{cases} I(V_{oc}) = 0 \\ I(0) = I_{sc} \\ I(V_{mpp}) = I_{mpp} \\ \left.\frac{dP}{dV}\right|_{P=P_{mpp}} = I_{mpp} + \left.\frac{dI}{dV}\right|_{V=V_{mpp}}^{I=I_{mpp}} = 0 \end{cases} \tag{9}$$

2) *Two diode model*

This model takes into account the mechanism of electric transport of charges inside the cell. In the model "two diodes", the two diodes are present for the PN junction polarization phenomena. These diodes represent the recombination of the minority carriers, which are located both at the surface of the material and within the volume of the material (Fig.3.).

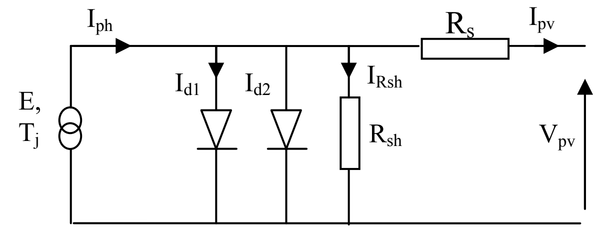

Fig.3.Equivalent circuit for two diode model

The following equation is then obtained:

$$I_{pv} = I_{ph} - (I_{d2} + I_{d2}) - I_{Rsh} \tag{10}$$

With: I_{ph} and I_{Rsh} maintaining the same expressions as above. For the recombination currents, we have:

$$I_{d1} = I_{01}\left[\exp(\frac{q.(V_{pv}+R_S.I_{pv})}{A.N_s.k.T_j})-1\right] \tag{11}$$

$$I_{d2} = I_{02}\left[\exp(\frac{q.(V_{pv}+R_S.I_{pv})}{2.A.N_s.k.T_j})-1\right] \tag{12}$$

The saturation currents are written as:

$$I_{01} = P_4.T_j^3.\exp\left(\frac{-E_g}{k.T_j}\right) \tag{13}$$

$$I_{02} = P_5.T_j^3.\exp\left(\frac{-E_g}{2.k.T_j}\right) \tag{14}$$

With N_s is the number of cells in branched series, E_g represents the gap energy

The final equation of the model is thereby written as:

$$I_{pv} = P_1.G[1+P_2(G-G_{ref})+P_3(T_j-T_{ref})] - \frac{(V_{pv}+R_s.I_{pv})}{R_{sh}} - P_{04}.T_j^3.\exp\left(\frac{-E_g}{k.T_j}\right)\left[\exp\left(q.\frac{V_{pv}+R_s.I_{pv}}{A.N_s.k.T_j}\right)-1\right] - P_{14}.T_j^3.\exp\left(\frac{-E_g}{2.k.T_j}\right)\left[\exp\left(q.\frac{V_{pv}+R_s.I_{pv}}{2.A.N_s.k.T_j}\right)-1\right] \tag{15}$$

3) *Third model*

This model is characterized by a very simple resolution. It requires only four parameters namely I_{sc}, V_{oc}, V_{mp} and I_{mp}. The I_{pv}-V_{pv} characteristic of this model is illustrated as follows:

$$I_{pv} = I_{sc}\left\{1 - C_1\left[\exp\left(\frac{V_{pv}}{C_2.V_{oc}}\right) - 1\right]\right\} \tag{16}$$

With:

$$C_2 = \frac{\left(\frac{V_m}{V_{oc}}\right) - 1}{\ln(1 - \frac{I_m}{I_{sc}})} \tag{17}$$

$$C_1 = (1 - \frac{I_m}{I_{sc}})\exp(-\frac{V_m}{C_2.V_{oc}}) \tag{18}$$

The constant parameters can be determined directly by equations (17, 18).

B. *Simulation under Matlab/Simulink:*

In our work, we use the one diode model. The block diagram is given [5](Fig.4.)

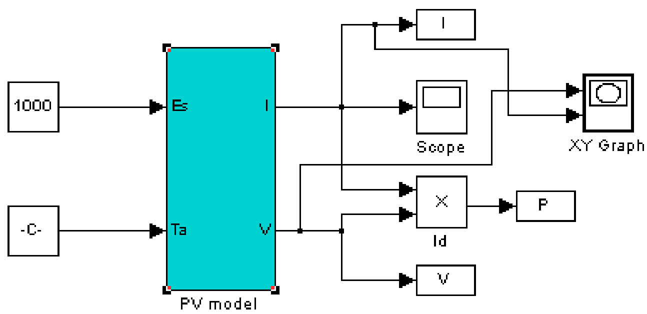

Fig.4.Block diagram of the PV model

IV. CLASSICAL METHOD WITH A VARIABLE RESISTIVE LOAD

We obtain electrical characteristics through the following experimental bench (Fig.5.). It consists if a PV panel, two multimeters and a variable restive load [5].

Fig.5. Experimental bench of the classical with a variable resistive load

V. METHOD USING LABVIEW™ SOFTWARE

We use the following experimental bench (Fig.6.).

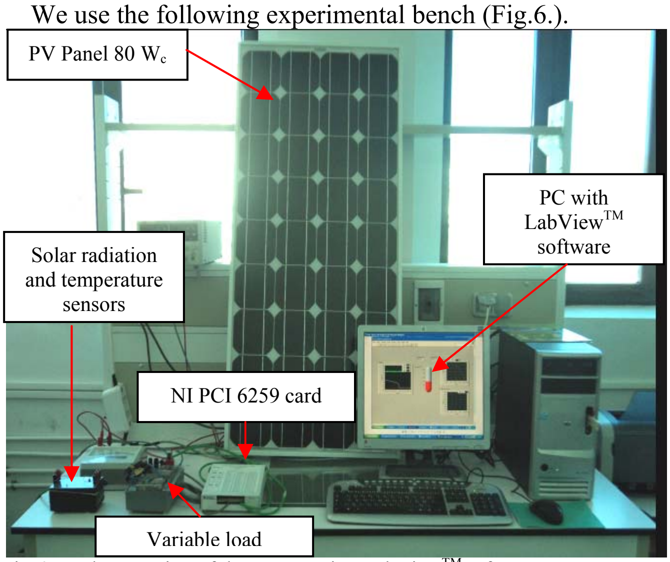

Fig.6. Implementation of the systemusing LabView™ software.

For the system acquisition, we use a NI PCI 6259 card of National Instruments [6] and LabView™ software [7-9].

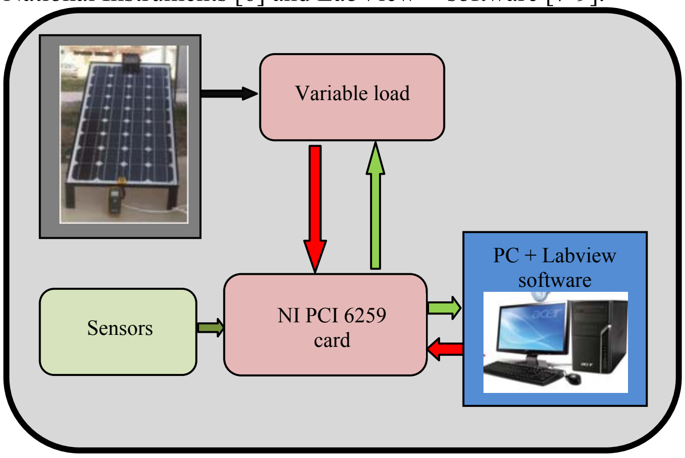

Fig. 7. Block diagram of the system characterisation.

A. Identification of climatic parameters

The block diagram of the measurement card consists of a sensor solar radiation, a temperature sensor and a symmetrical supply

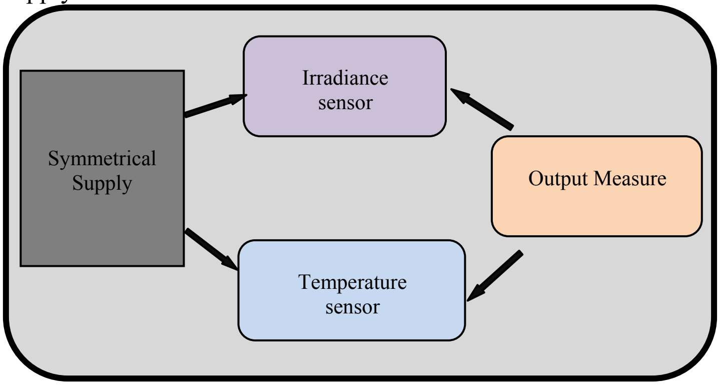

Fig.8. Block diagram of the measurement card .

Fig 9. Solar radiation and temperature sensors

B. Identification of electrical parameters of the photovoltaic panel

To measure electrical parameters, the PV system must insert a variable load wich allows to absorb the power of the photovoltaic panel. The measurement card contains a voltage sensor, a current sensor, a variable load and a control loop (Fig.10).

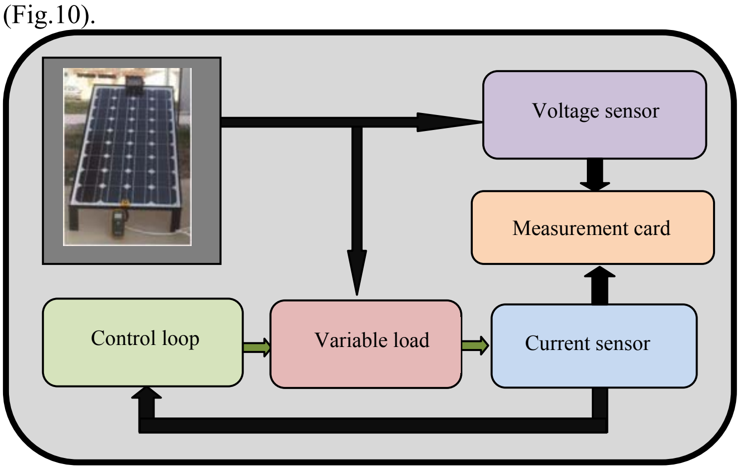

Fig.10.Block diagram of a measuring circuit.

The voltage sensor selected is a simple voltage divider. It serves to divide the voltage of the PV module as a value capture card supports up to 10V maximum. The current sensor is a sensor shunt which is a resistor of small value, it absorbs a large current which is measured at its terminals a voltage which is divided by the value of this resistor, then the absobed current is obtained. The operational amplifier LM358 is a critical component in this embodiment it allows the current adjustment with respect to a reference which is used as a comparator. This comparison generates a ball-type proportional control between the output and the reference imposed. This reference is sent by the card represents the image acquisition and current. The output of the comparator directly attack the base of the transistor TIP111.The variable load is based on two power transistors. A 2N3055 Bipolar NPN Darlington and a NPN TIP111 (Fig.11).

Fig.10. Variable load

C. *Data acquisition unit*

For controlling the measuring card and the different climatic and electrical parameters, LabView^{TM} software is implemented (Fig.11.). Its program consists of four steps:

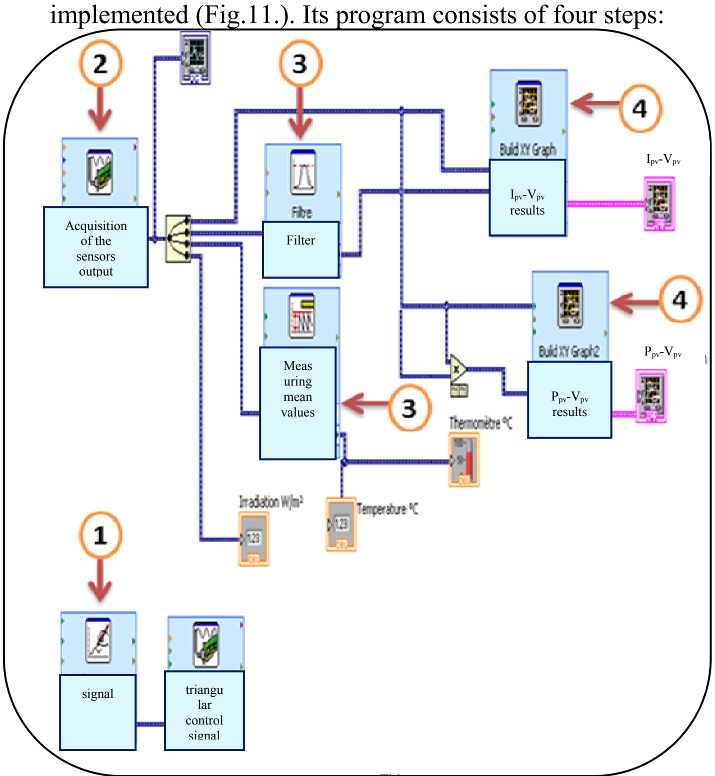

Fig11. Block Diagram of the LabView^{TM} software Simulation

¬ Step 1: This step consists to send from the acquisition card NI PCI 6959 a triangular control signal representing the current image.

¬ Step 2: After sending the control signal, follows the step of acquiring the sensors output signals.

¬ Step 3: This step is performed to process data acquired by the data acquisition. It is constituted by a filter and an instrument measuring the mean value.

¬ Step 4: After acquisition and filtering data, the results can be shown (Graph).

VI. Obtained Results under the three Methods

We make three tests (low, medium and high irradiation) for each method.

- Test N°1: T= 31.79°C, Es=201.9 W/m².
- Test N°2: T= 35.60°C, Es=530.41W/m².
- Test N°3: T= 34.40°C, Es=729.61 W/m².

We obtain the following characteristics (Fig.12-14). We remark a concordance between the three methods. We note some errors especially in low irradiations which are due to measurement errors by irradiance and temperature sensors. Obtained results in the third method are more accuracy in measurement and we obtain a larger number of points on a defined scale of time.

Conclusion

In this paper, we have presented electrical PV characteristics obtained with three different methods and under different meteorological tests conditions. The obtained results are compared. By using LabView^{TM} software, the data acquisition system allows measuring the values of current and voltage, to simultaneously trace electrical characteristics in real time. Experimental results in real time agree with the Simulation ones.

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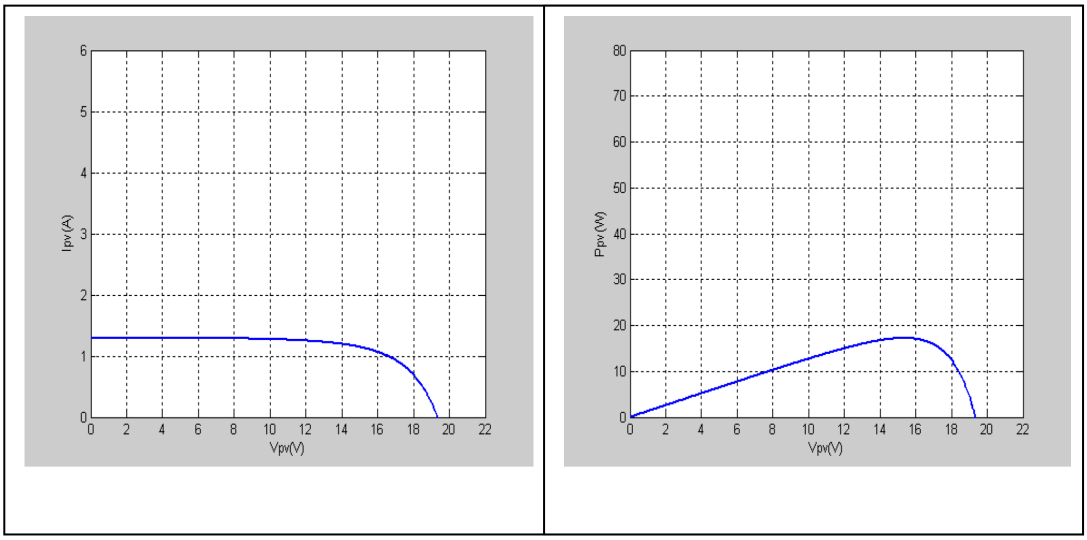
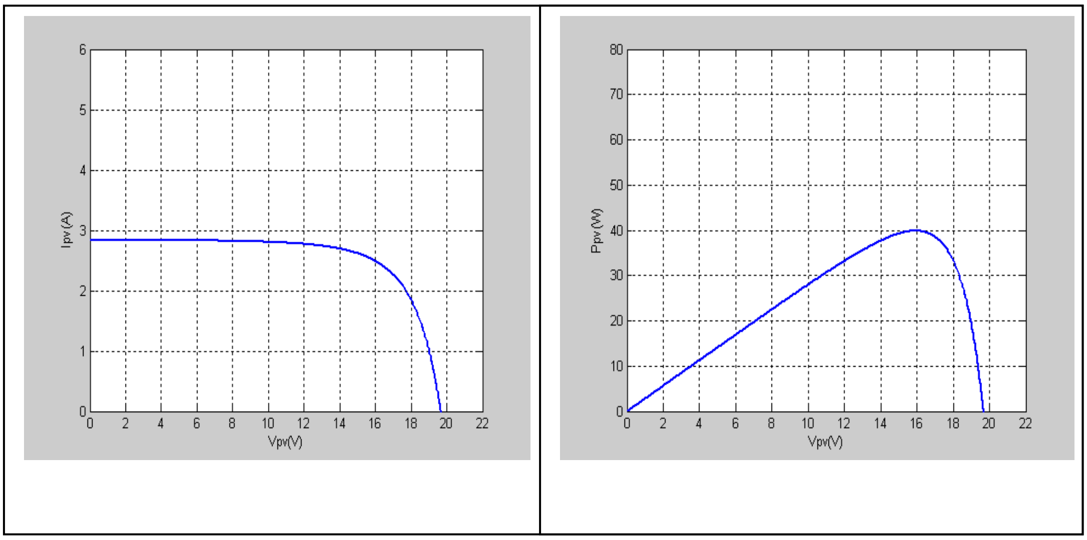
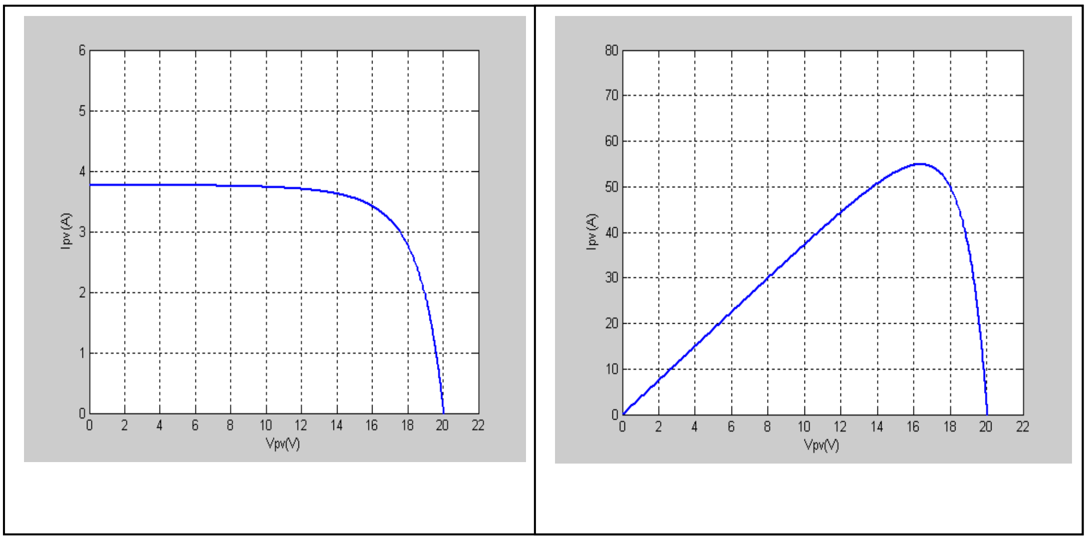


Test N°1

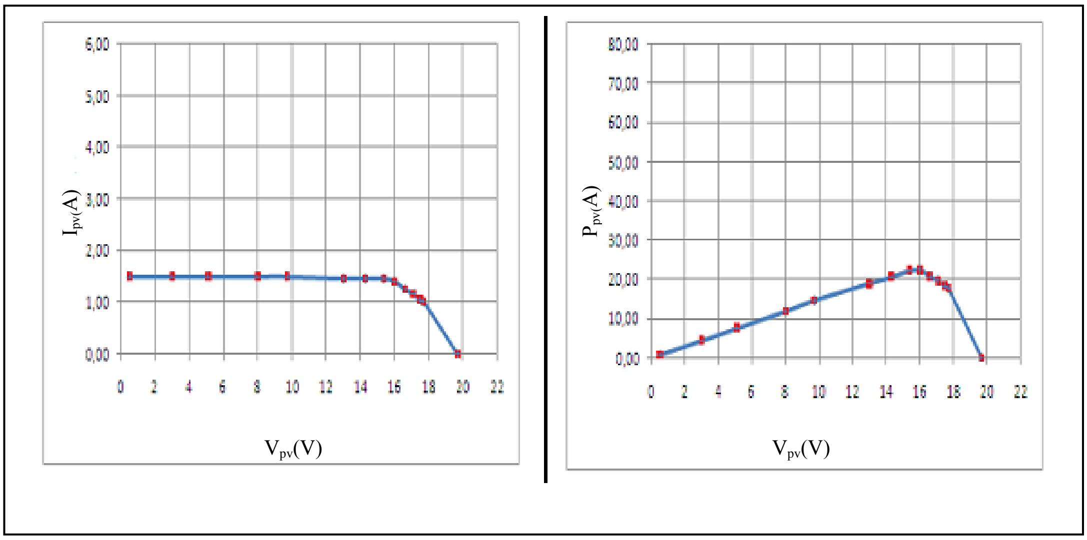


Test N°2

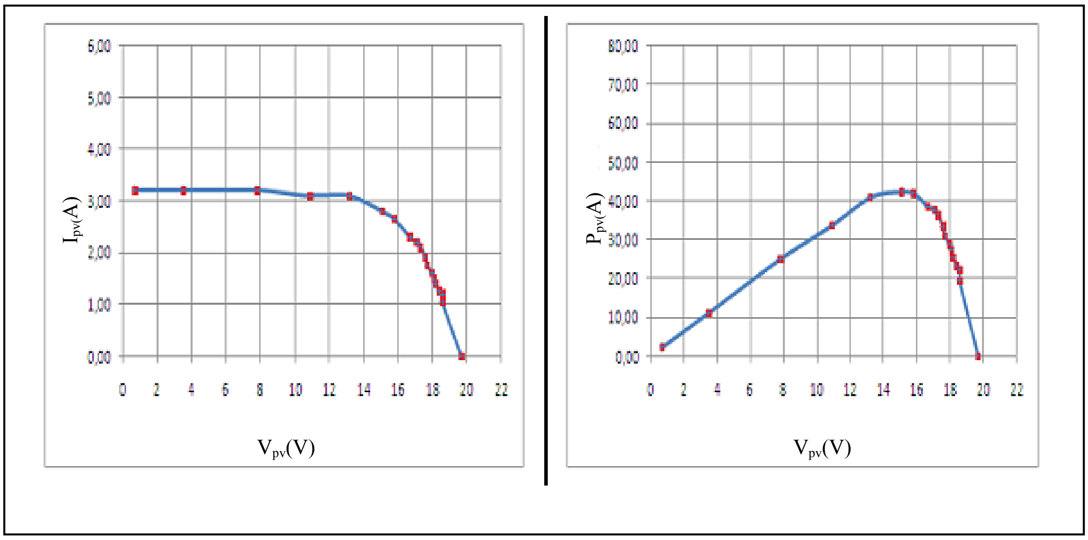


Test N°3

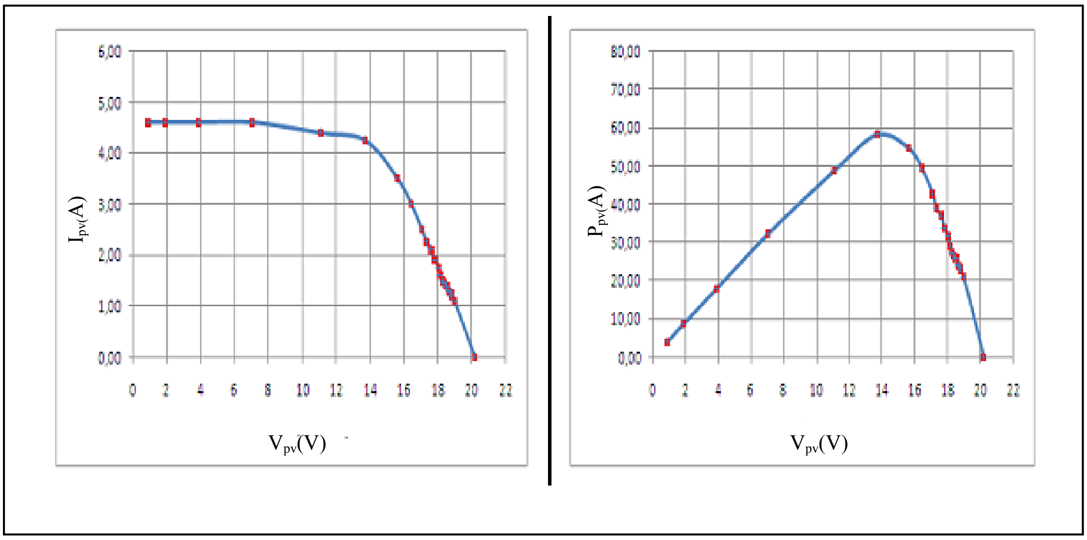
Fig 12. I_{pv}-V_{pv} an P_{pv}-V_{pv} caracteristics under Matlab/Simulink for the three tests.



Test N°1

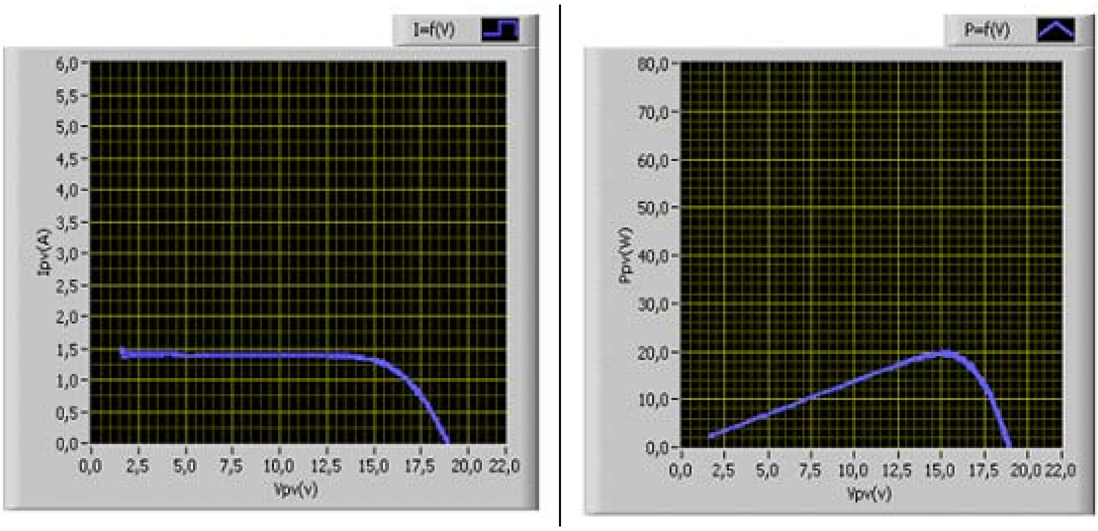


Test N°2

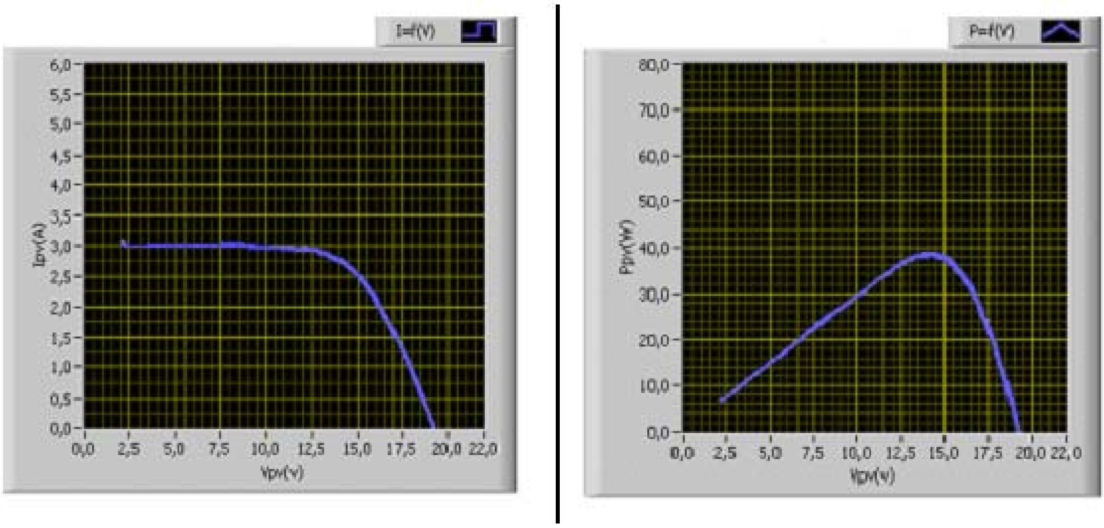


Test N°3

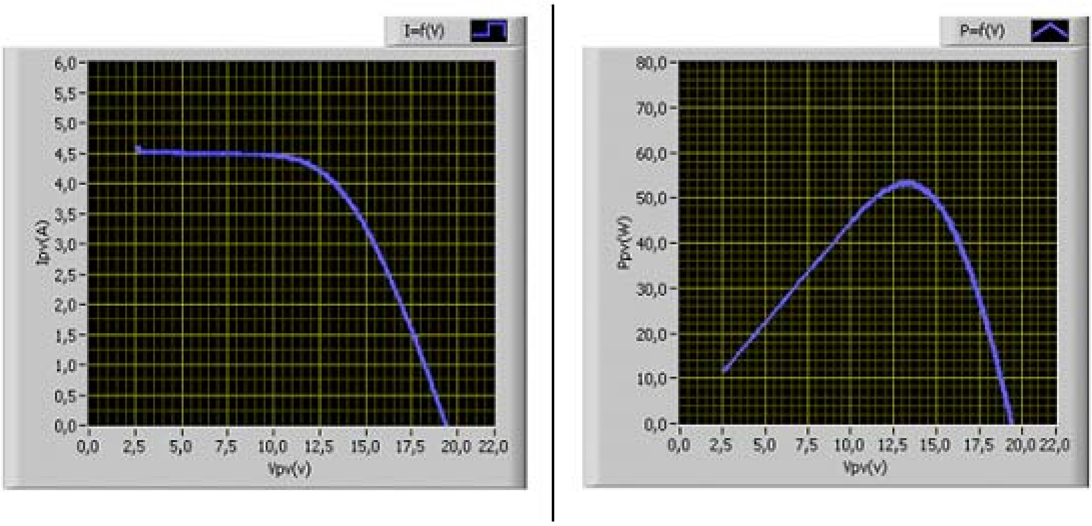
Fig 13. I_{pv}-V_{pv} an P_{pv}-V_{pv} caracteristics under clasical method with variable load for the three tests.



Test N°1



Test N°2



Test N°3

Fig 14 I_{pv}-V_{pv} an P_{pv}-V_{pv} caracteristics under with LabView^{TM} software for the three tests.