Design and implementation of a system for characterizing solar module

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Abstract:

The quality of photovoltaic generators (GPV) installed so far could only be controlled through expensive measurement system. Two important points are discussed in the context of this work. The first section looks at the development of an automatic characterization of PV module based on a PIC microcontroller (PIC16F877A).

We present in the second part a practical evaluation of the electrical performance of a solar module with amorphous silicon a-Si: H hybrid (thin film inorganic / organic substrate) in real-time operating conditions, facing south with an angle of 38 ° which is the optimum orientation for the city of Oran (Algeria).

Keywords:

Automatic measure, amorphous silicon, PV hybrid module, characterization, thin film, morphology and electrical performance.

I. INTRODUCTION

The photovoltaic (PV) produced by solar cells manufacturers is increasingly considered as a source of energy that can contribute to global electricity production while contributing to sustainable development. The PV industry is concentrated to near 99% using silicon as base material **[1]**. Currently, the cost of silicon in the development of a PV panel can reach 50% of total costs, it is clear that reducing the cost of the module through reducing the cost of developing the substrate the most accessible for industry is to reduce the thickness of silicon Polack, while using cheap substrates **[2]**. Other materials are also used, cadium telluride (CdTe), the diselenide and copper indium (CIS) and gallium (CIGS). These technologies based on thin films are still very expensive but, promising returns and life at least equivalent to silicon.

II. SOLAR CELLS IN THIN FILMS

A. The hydrogenated amorphous silicon (a-Si :H)

At its first introduction in the early '60s, it was not usable because it contained many defects that were limiting performance. After ten years, it was found that the use of a plasma of silane (SiH_4) for the deposit of a-Si: H allowed to obtain a material or 99.9% of the defects was saturated (passivated) by hydrogen **[3].** From that time, research on hydrogenated amorphous silicon has intensified, particularly in the field of photovoltaic solar cells in thin layers. That popularity was mainly due to the fact that these films have a coefficient of absorption of sunlight by several orders of magnitude higher than that of crystalline silicon and are often produced directly from the gas phase. Thus, a PV module in thin films can be produced in a layer 400 times thinner than crystalline PV cell with an area 40 times larger.

It seems clear that the costs should be much lower, the availability of basic materials greater and the manufacturing process easier **[4]**.

B. Films on plastic substrate

Although plastic polymers have several advantages over glass substrates, these substrates are more easily integrated into industrial processes (cutting, continuous production), their lightness and lower cost paving the way for new applications. Moreover, these polymeric materials absorb in the UV which reduces the problems of instability of hybrid cells. The use of these substrates leads nevertheless some disadvantages, since most of the polymers do not tolerate temperatures above 140 ° C which does not allow a good connection between the particles and good adhesion to substrates. In addition several plasticizers present in these substrates diffuse

into the cell, which affects the performance of these cells.

III. DEVICES AND SENSORS FOR MEASURES

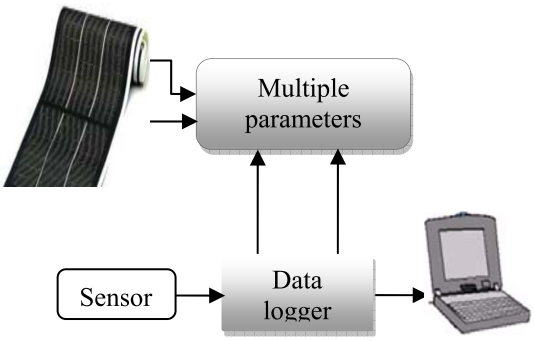

Figure 01: Block diagram of the characterization system.

The measuring device consists primarily of a microcontroller (16F877A) and a set of sensors: a calibrated temperature sensor LM35DZ, two light sensors, respectively LDR05 photoresistor and a photodiode BPW21, and finally, a bridge divider and a low value shunt resistor are used for sensing the voltage and current of PV module.

A. Measure climatic parameters

- **Temperature Measurement**

We used the analogue temperature sensor LM35DZ. The temperature is converted into low voltage, and is factory calibrated so as to have 0V at 0 ° C with a slope of 10mV / ° C.

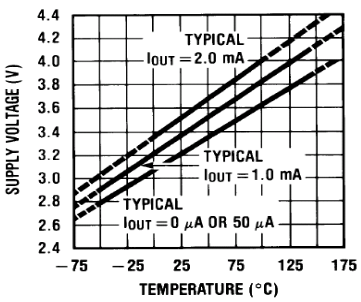

Figure 02: Characteristic Voltage / Temperature of LM35.

- **Measure illuminance**

We used two photo-detectors with different characteristics, i.e., a photoresistor and a photodiode.

1. The photoresistor (LDR05)

It is a dipole semiconductor without junction whose resistance varies when it is exposed to light in a certain range of wavelength.

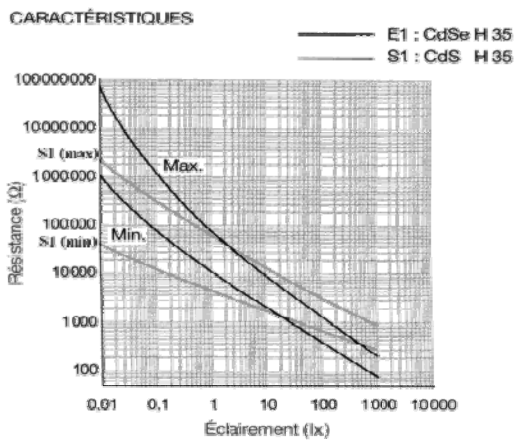

Figure 03: Characteristic of the LDR05.

2. The photodiode (BPW21)

A photodiode is considered as a basic photodetector of most optoelectronic sensors, it is the element responsible to convert light energy into electrical energy. The photodiode under illumination, generates a current that depends on its spectral responsivity and luminous flux incident

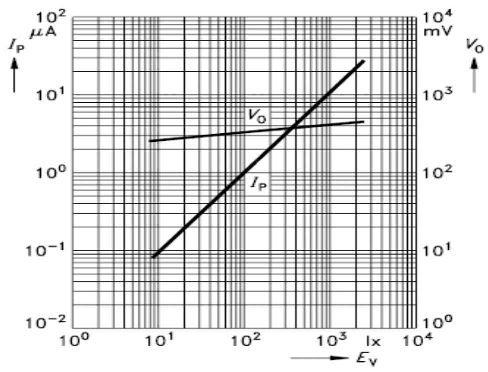

Figure 04: Characteristics of the used photodiode (BPW21)

B. Data acquisition unit

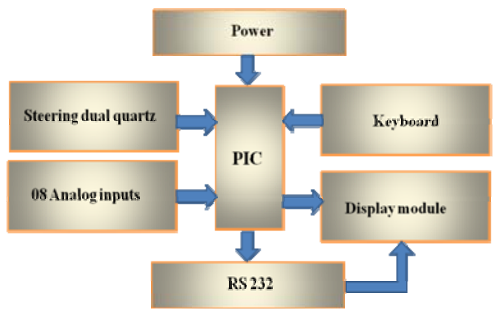

Figure 05: Block diagram of the datalogger.

The PIC is responsible for converting the analogue electrical signal into digital values that are displayed in real time using a four seven-segment digits display;

these values are stored in its internal EEPROM, which will then be downloaded to a PC through the serial port RS232 for handling, visualization and recording results. The power of the card is provided by batteries LR6 (Lithium 3Ah); this high performance power unit ensure for a substantial autonomy period. To maximize the duration of this autonomy, we imposed the following facts:

1. Reduced consumption of display: using double multiplexing **[5]**: a classical multiplexing per digit, and a multiplexing per segment, which has enabled us to reduce significantly I_{DD} ;

2. Flashing display (visibility 33% of 1 second) ;

3. Automatic turn off the display after the acquisition phase.

C. Variable electronic load

This system characterization is designed to drive automatically a variable electronic load through a 7-bit digital to analog converter (C.N.A.) using weighted resistances. We can automatically measure up to 128 pair (I, V).

- **Electrical diagram**

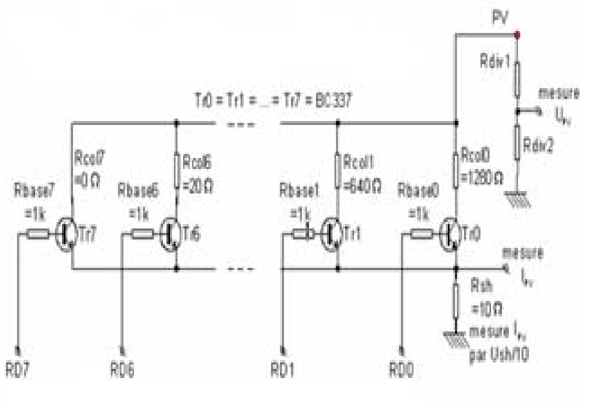

Figure 06: Bipolar transistors based variable load mounted as a 7-bit weighted digital to analog converter (CNA)

- **Principle of method**

The principle of this method is to set points chosen in a way that they are distributed in a manner more or less equidistant across the range of the characteristic I (V) module. To achieve this and to have the maximum number of points possible (up to 256 steps, limit of the PIC EEPROM). The number of transistors used is eight, driven through their current base and they function as switches (saturated or blocked); therefore, values of collector current (Ic) are imposed by the resistance of collectors for well-defined setting points of measurements.
The choice of transistors is determined by the critical values of the module to be characterized; in our case it is a module with Voc = 6V and Icc = 300 mA. We opted for the BC337 transistor (V = 45V, I = 800mA).

IV. PRINCIPLE OF MEASUREMENT

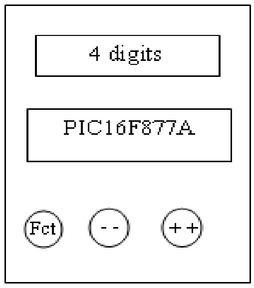

Figure 07: Block diagram of the measuring device

STEP 1: Acquisition of measures and storage in the EEPROM

When powered on, this device goes to state 1 :
hour = 00: 00 by default
State 1: Adjusting **hours**: increment (+ +) or decrement (- -);
Press the button (Fct) to go to state 2, otherwise, after 10s, the device switches to automatic acquisition.
State 2: Setting **minutes:** increment (+ +) or decrement (- -);
Press the button (Fct) to go to state 3, otherwise, after 10s, the device switches to automatic acquisition.
State 3: Automatic acquisition mode
The device switches to automatic acquisition: 1 measurement / second, with storage in EEPROM. Display (flashing 33% of 1s) successively channel 1 (measurement I) and channel 2 (Measure V), in closed loop; autonomous acquisition of 256 measures (128 measurements for I and 128 steps for V) and then the display is turned off to save battery life.

STEP 2: Transfer of the EEPROM to a PC via the RS232 serial link

1. Connect the plug DB9F to serial port COM1 of a PC compatible.
2. Launch the program “Mv8chnv3.exe”, and configure the serial link for a transfer 8N1 - 115200 baud, without protocol. Finally, click on the "Start" button.
3. Short press on the button "Fct" from the datalogger to start the transfer of the 256 measurements stored in EEPROM to the PC.
4. Once finished, click the button "Stop", then copy and paste the contents of the Memo area of the program “Mv8chnv3.exe” to a spreadsheet (e.g. Excel) for data analysis and drawing charts.

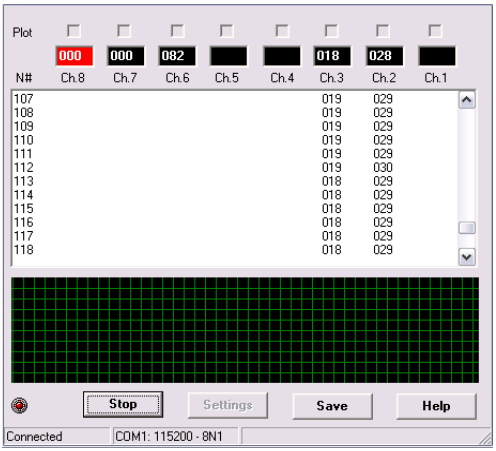

Figure 08: GUI the acquisition phase on PC

V. EXPERIMENTS AND RESULTS

The module used to validate the system developed and implemented in this study is a thin layer module-based of amorphous silicon deposited on a flexible substrate, in operation since 2004.

A. *Optoelectronic Characteristics*

Several tests were performed in different conditions, we were led to recalculated several components of the electronic charge level to full scale current and voltage, as shown in the figures below:

Test 01 : 20/08/2009 at 13h24

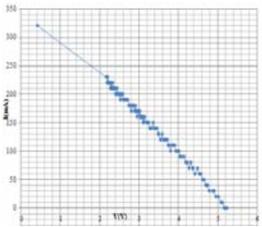

Figure09: CharacteristicI-V.

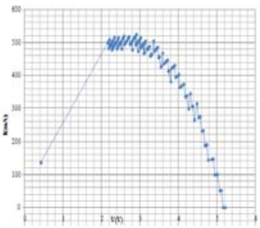

Figure10 : CharacteristicP-V.

Test 02 : 23/08/2009 at 16h00

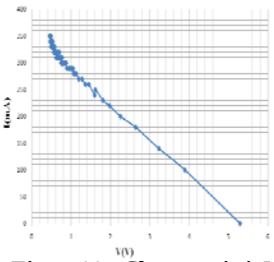

Figure11 : Characteristic*I-V.*

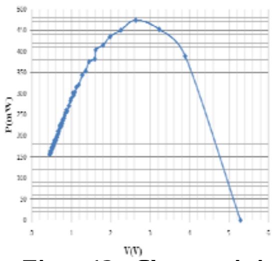

Figure12 : Characteristic*P-V.*

Test 03 : 21/08/2009 at 12h27

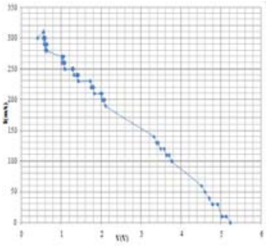

Figure13 : Characteristic*I-V.*

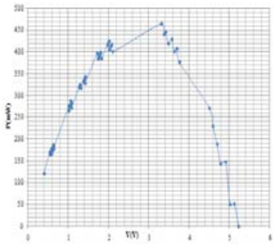

Figure14 : CharacteristicP-V.

To check the validity of the designed system, we decided to renew these series of tests for different types of photovoltaic modules.

Test 04 : Monocrystalline silicon module (Voc = 21V, Icc = 130mA)

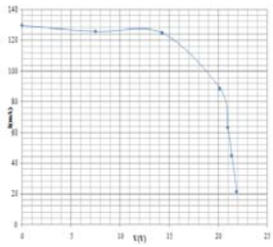

Figure15 : Characteristic*I-V.*

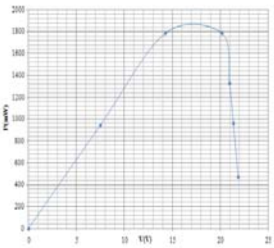

Figure16 : CharacteristicP-V.

Test 05: Amorphous silicon cell in a non-flexible substrate (Voc = 2.68V, Icc = 556mA)

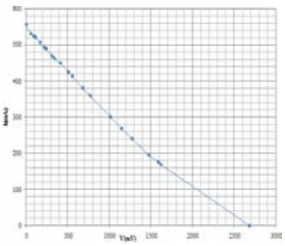

Figure17 : Characteristic*I-V.*

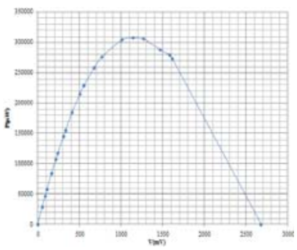

Figure18 : CharacteristicP-V.

Test 06 : Module en silicium amorphe (a-Si :H) déposé sur un substrat flexible Voc=5.4V,Icc=330mA) (21/08/2009 à 15h27)

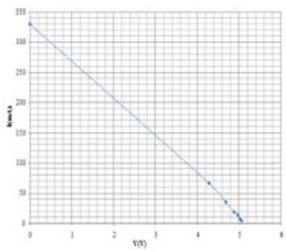

Figure 19: Characteristic *I-V.*

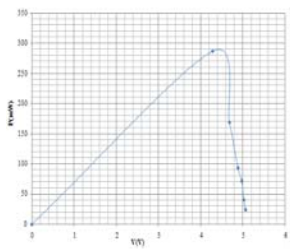

Figure 20 : Characteristic *P-V.*

- **Model comparison**

The typical solar module can be electrically modelled as a current source Isc shunted by m diodes in series, the diodes are considered ideal **[6][7]**. Below are presented the curves I (V) and P (V) of the ideal model, considering the ideal values of resistors Rs and Rsh PV module **[8][9][10]**.

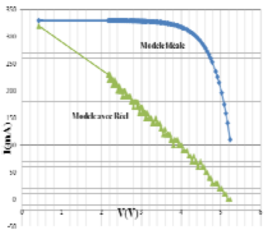

***Figure 21**: Comparison of characteristics I-V*

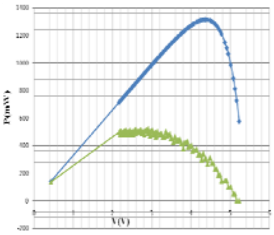

***Figure 22:** Comparison of characteristics P-V*

VI. INTERPRETATION OF RESULTS

The results obtained show that the characteristic I (V) of solar hybrid module (thin film inorganic and organic substrate) differs from the typical conventional crystalline modules and it has a linear characteristic with a very low form factor FF = 30 %; several factors may explain the linearity of the characteristic:

A. Serie resistor : (Rs = 5.09 Ω), it takes into account the specific resistivity of the contacts between the various constituent regions of the cell;

B. Shunt resistor: (Rsh = 22 Ω), it shows the strength of short circuit; it reflects the existence of shunt through the transmitter, caused by a defect in the structure of the cell;

C. The substrate: Most polymers do not tolerate temperatures above 140 ° C, which does not permit a good connection between the particles and good adhesion to substrates and therefore decrease the efficiency of the cell;

D. Steabler-Wronski effect: the degradation over time, this stabilization is a phenomenon specific to amorphous materials, and is notorious for its disastrous consequences on the performance of cells. It was discovered by Steabler and Wronski 1977, and is characterized mainly by the slow decrease of the photoconductivity δph under high irradiance, there is also decrease the conductivity in the dark δd.

VII. CONCLUSION

The results obtained show that the designed system tool validates the conventional model of photovoltaic conversion; on the other hand, this new measurement system now allows engineers to benefit from a handy, low cost and simple small measuring device. This work presents a practical approach to the characterization of a PV energy system, and gives an idea of the critical points where the design must be carefully optimized.

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