

Design and implementation of an I-V curvetracer dedicated to characterize PV panels

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ABSTRACT

In recent years, solar photovoltaic energy is becoming very important in the generation of green electricity. Solar photovoltaic effect directly converts solar radiation into electricity. The output of the photovoltaic module MPV depends on several factors as solar irradiation and cell temperature. A curve tracer is a system used to acquire the PV current-voltage characteristics, in real time, in an efficient manner. The shape of the I-V curve gives useful information about the possible anomalies of a PV device. This paper describes an experimental system developed to measure the current-voltage curve of a MPV under real conditions. The measurement is performed in an automated way. This present paper presents the design, and the construction of I-V simple curve tracer for photovoltaic modules. This device is important for photovoltaic (PV) performance assessment for the measurement, extraction, elaboration and diagnose of entire current-voltage I-V curves for several photovoltaic modules. This system permits to sweep the entire I-V curve, in short time, with different climatic and loads conditions. An experimental test bench is described. This tracer is simple and the experimental results present good performance. Simulation and experimental tests have been carried out. Experimental results presented good performance.

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1. INTRODUCTION

Solar photovoltaic energy is becoming favored as renewable energy. Solar photovoltaic (PV) energy is a renewable energy source that is available all over the world. To characterize a PV device, the determination of I-V (current versus voltage) curve is an important information to know the electrical performance of the PV panel. The I-V characteristics of photovoltaic panel has a remarkable shape. Distinct curve tracers [1, 2] exist within the literature; separating each technique are differences in cost, speed, complexity. There are several papers describing different methods to characterize I-V curves of photovoltaic panels [1, 2]. It is shown that these methods are distinguished in implementation. The different methods as for example capacitive load, electronic load, bipolar power amplifier, four-quadrant power supply; DC-DC Converter are given in [1]. In this work, a portable and simple photovoltaic voltage versus current curve tracer is discussed. The aim of this present study is to introduce and to develop a simple and a useful data

acquisition system to measure I-V curves in situ, to characterize photovoltaic panels. Some information such as the maximum power point, the short-circuit current and the open circuit voltage can be taken from the measurements.

2. PROPOSED METHOD FOR ELECTRICAL MODEL

The solar cell is a nonlinear device [3-19] and can be represented as a current source model, as shown in Figure 1.

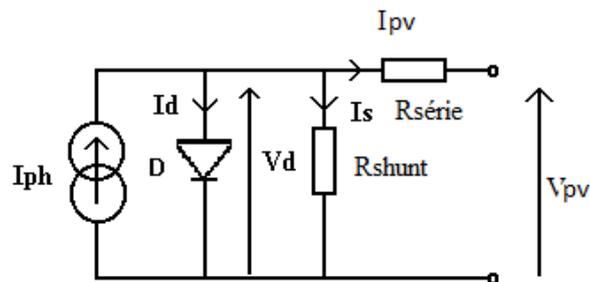


Figure 1. Equivalent circuit of the single-diode model

$I_{ph} \approx I_{cc}$: Short-circuit current.

I_d : Diode current.

R_s : Solar cell intrinsic series resistance whose value is usually very small.

R_{sh} : Equivalent shunt resistance of the solar cell whose value is usually very large.

$I_{pv}=I$: Current output.

$V_{pv}=V$: Voltage output.

In our case, a photovoltaic panel is constituted of 36 solar polycrystalline cells in series (Kyocera LA 361 K51) tilted at 35° angle facing south. PV panel is characterized by its current-voltage (I-V) curve. Different models of solar cells were presented in literature [3-10]. The relationship of current –voltage (I-V) for a photovoltaic panel is [11, 12]:

$$I = \frac{I_{cc}(V_{oc}-V)}{V_{oc}+BV^2I_{cc}-CV} \quad (1)$$

where V_{oc} is the open-circuit voltage, I_{cc} is the short-circuit current.

B and C are constants determined by:

$$B = \frac{K_1-K_2}{K_3} \quad (2)$$

$$C = \frac{K_1V_1-K_2V_2}{K_3} \quad (3)$$

Two points of coordinates (I_1-V_1) , (I_2-V_2) taken either side of the maximum power point.

$$K_1 = V_1I_1(V_{oc} - V_2 - AI_2) \quad (4)$$

$$A = \frac{V_{oc}}{I_{cc}} \quad (5)$$

$$K_2 = V_2I_2(V_{oc} - V_1 - AI_1) \quad (6)$$

$$K_3 = V_1I_1V_2I_2(V_2 - V_1) \quad (7)$$

Constants B and C depend on the following panel parameters:

- Short circuit current I_{cc} ;
- Open circuit voltage V_{oc} ;

Standard conditions are insulation $E_s=1\text{kW/m}^2$, corresponding to $E_s=1$ sun, and temperature $T=25^\circ\text{C}$. Figure 2 shows for our panel as shown in the Table 1 the I-V curves at different levels of insulation (at $T=25^\circ\text{C}$) [5-10]. The photovoltaic panel characteristics, like any other semiconductor component is affected by temperature change. I-V obtained characteristics are shown respectively on Figure 3 [3-10].

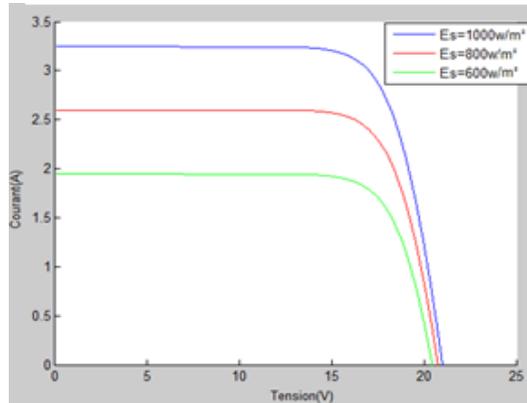


Figure 2. Plots of the proposed function (1) for increasing values of E_s , $T=25^\circ\text{C}$

Table 1. Characteristics of the PV panel Kyocera La 361 K51

Variable	Value
P_{max}	51 W
V_{oc}	21.2 V
I_{cc}	3.25 A
V_{opt}	16.9 V
I_{opt}	3.02 A

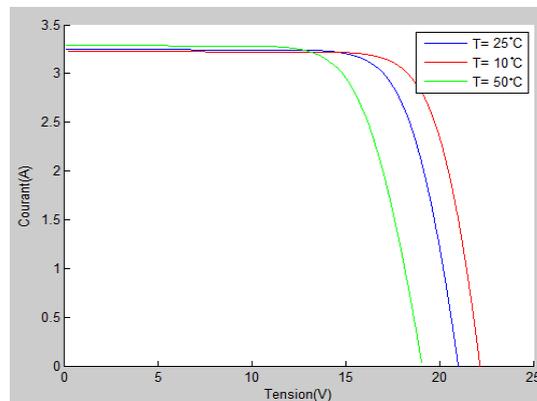


Figure 3. Plots of the proposed function (1) for increasing values of T , $E_s=1$ sun

3. RESEARCH METHOD

It is important to measure current voltage curve for monitoring the performance of the PV panels. Recently, a concept for fully I-V tracers was reported [19-27]. Our realization is a portable and simple on line I-V tracer. It works in real time. This method uses a bipolar junction transistor as the load connected to the PV panel as shown in the Figure 4. The transistor acts as a variable resistor at the terminal of the PV panel. The transistor base current I_b is controlled so that the collector current scan the entire current range of the panel. The control is ensured by a progressive rise of the base current I_b . To do this, we used a controlled voltage which varies in proportion to the current (I_b). By this changing in a suitable range, the measuring points can sweep between I_{cc} and V_{OC} . Thus, this voltage evolves in steps from zero, up to the maximum value which ensures the saturation of the transistor. Hence, we have the short circuit I_{cc} of the photovoltaic panel. The collector current I_c , in turn increases and the voltage V_{CE} decreases. To control I_b , a

microcontroller or a function generator can be used to provide a ramp or a sinusoid wave current signal to the base of the transistor. The Figure 5 shows the circuit designed to trace the I-V curves for photovoltaic panel.

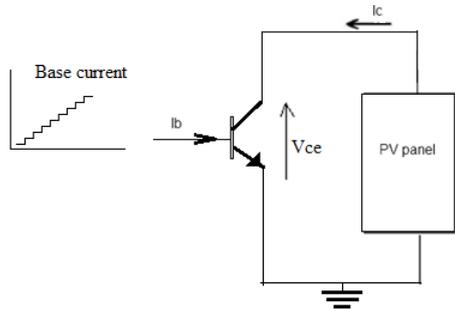


Figure 4. Bipolar transistor as an electronic load connected to photovoltaic panel

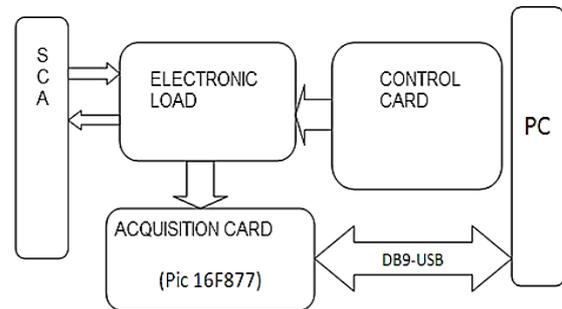


Figure 5. Overall schematic diagram of the system realized

The scanning of the I-V characteristic of the panel is reproduced by taking of samples over the full range current and voltage. A test bench is designed and built. Our test bench, in Figure 5 consists essentially of:

- Circuit of control of the transistor (a signal generator in stairs) and power circuit for amplifying the control voltage to adapt to the power transistor.
- A measurement card and conditioning of different analog quantities (current, voltage).
- A microcontroller 16F877 in a serial link with the PC provide the voltage and current acquired from sensors.

The realized system, allows measurement of I,V and save the system response (current, voltage and therefore power). To summarize, our experimental test bench comprises three main parts: power part, command part and acquisition part. The control circuit is a stair signal generator built around NE555 integrated circuit, 2 Synchronous 4-bit Counter 74LS163 and a bridge of resistances as seen in Figure 6.

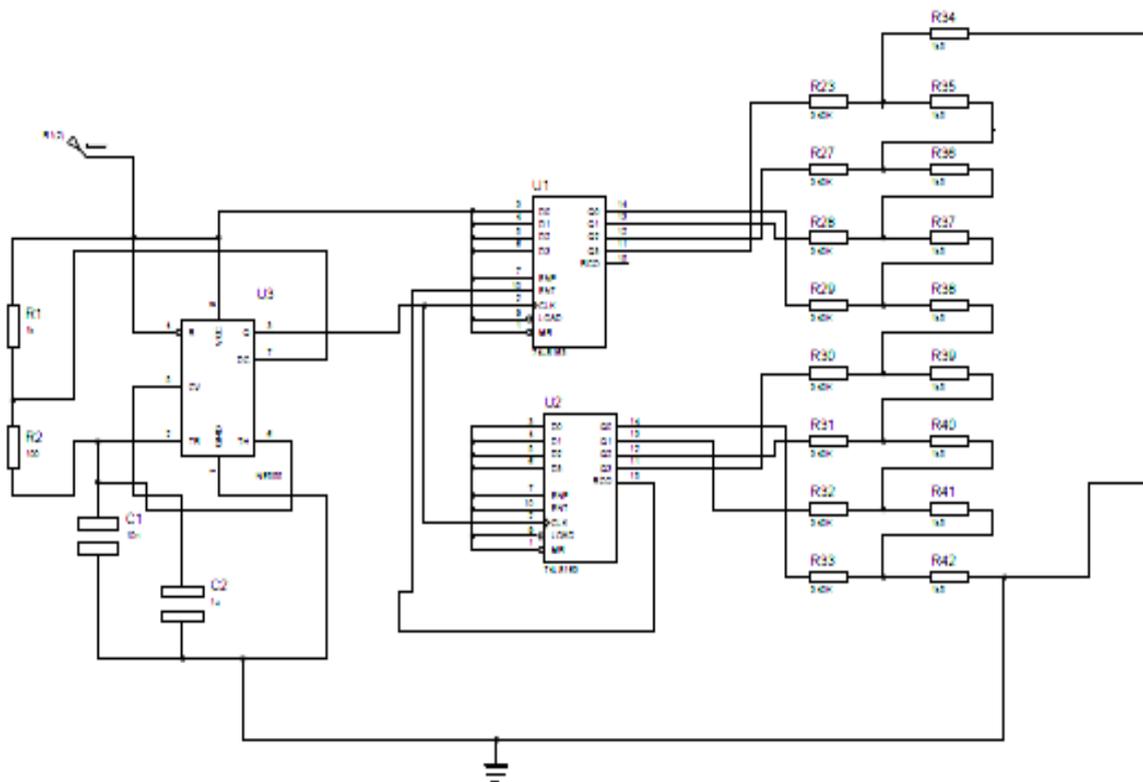


Figure 6. The control circuit of the I-V curve tracer

The output of this system is applied to the input of a CNA in order to obtain a stair signal. The current of the photovoltaic panel can reach up to 3.25 A. The maximum voltage does not exceed 21.2 V under special conditions ($E_s = 1000 \text{ w/m}^2$, $T = 25 \text{ }^\circ\text{C}$). The potential advantage of this electronic load is a fast scanning of the equivalent load resistance. The transistor used as the variable load must be able to dissipate the power generated by the panel during the time of measurements. In addition, an appreciable gain would saturate the transistor from a low base current. The amplification of the base voltage is provided by an operational amplifier type LM324 as seen in Figure 7 which has as entry, the CAN output. The PV panel current and voltage I and V respectively are used and stored for treatment in PC, as seen in Figure 8. The circuit set up is shown in the Figure 9.

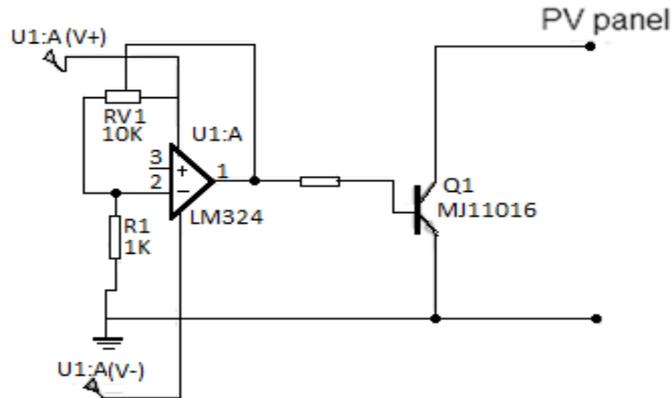


Figure 7. The amplification circuit of the I-V curve tracer

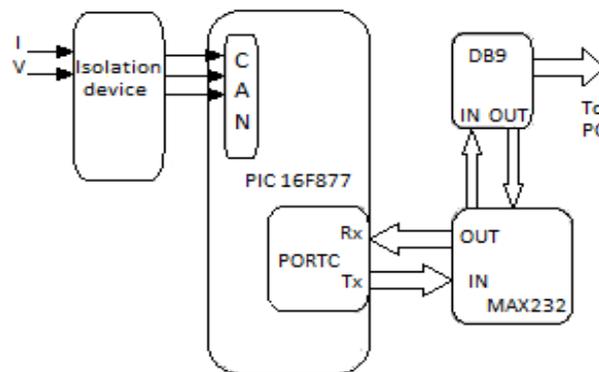


Figure 8. Synoptic diagram of the acquisition card



Figure 9. The circuit set up

4. RESULTS AND DISCUSSIONS

The Figure 10 illustrates the signal provided by the control circuit, in the practical tests. The Figure 11 illustrates the voltage and current signal versus time provided by the photovoltaic panel, in the practical test. The Figure 12 represents the I-V experimental characteristics of photovoltaic panel. For evaluating our method, we have performed several experiments, in different times and in more than one day which gave good results.

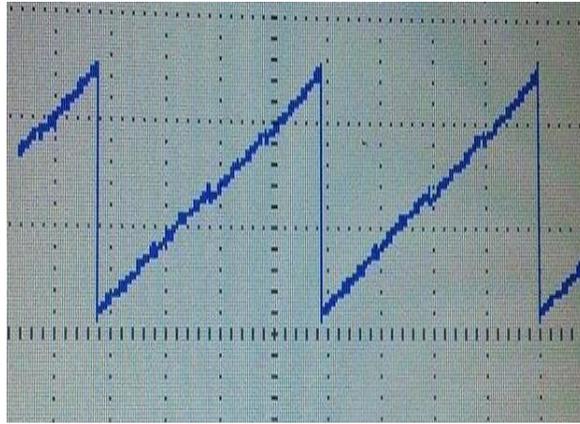


Figure 10. Experimental signal provided by the control circuit

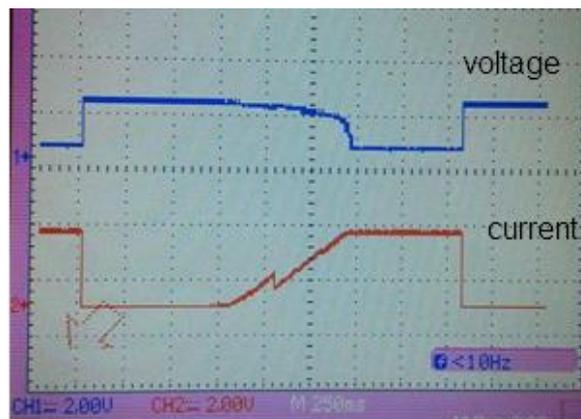


Figure 11. Experimental PV current signal and voltage signal versus time

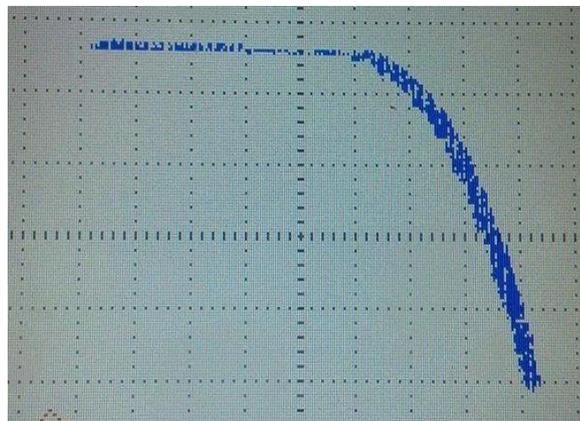


Figure 12. I-V experimental characteristic

5. CONCLUSION

This proposed curve tracer is an automatized process, in real time. It is clear that the proposed system is explicit and simple. It has some advantages: lower complexity, easy practical implementation, lower cost. This experimental bench can be used for acquire IV characteristics in variable climatic conditions, for different panels. It gives useful information about the possible anomalies of a PV panel. This device is important for photovoltaic (PV) performance assessment for the measurement, extraction, elaboration and diagnose of entire current-voltage I-V-curves.

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