DEVELOPMENT OF AN ELECTRONIC DEVICE FOR THE PHOTOVOLTAIC PAINEL CHARACTERIZATION

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Resumo:

The main objective of this study is to trace experimentally the characteristic curve of a photovoltaic (PV) panel. And for that, it is necessary to connect a variable resistor with the PV panel. In this case, it was used a circuit of electronic load to behave like a variable resistor, and as a consequence, this circuit has greater accuracy; and for that reason, it was developed a prototype to trace this curve. The prototype has three stages (signal generator, amplification stage and transistor stage) connect with a PV panel. was And for the first version of the prototype, witch part was designed to the PV panel KC40T. Also, it needed to build a power supply source to feed the amplification stage. Beyond that, with the right sizing of the parameters it is possible to trace the current-voltage curve of PV panel, since the open circuit voltage to the short circuit current. The prototype was built on a printed circuit board, and it contain two parts, one with the power supply and other with the main circuit. The circuit of electronic load was simulated to an irradiance of 1000W/m² and compared with the curve provide by the manufacturer. Then prototype was built in a printed circuit board and the results to an irradiance of 1050 and 850W/m² were compared with the simulation results. The simulated curve and the curve of the circuit of the electronic load were very clothe with each other, validating the prototype, however, it can be a way to minimize the error between the curves.

Palavras-chave: Amplifier, I-V curve, PV panel; Signal generator, transistor.

Modalidade de Participação: Iniciação Científica

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1 INTRODUCTION

The world is increasingly dependent of electricity, and because of that, there is a search of ways to produce it without degrade the environment. Currently, the energy source that most generates electricity is coal, however, the generation through renewable sources was increased in the last decade more than non-renewable sources in Brazil according to EPE (2017).

The type of renewable source that stands out is the solar energy, because it is a clean energy and can be used since a microgeneration as well as to large power plants. Therefore, it is important to understand how a photovoltaic (PV) system works. Moreover, the electrical behavior of these systems is represented by a current-voltage curve (*I-V curve*) (FOSTER, 2010).

The *I-V curve* contains the characteristics of a PV cell, where the main points are the short-circuit current (I_{sc}) and open-circuit voltage (V_{oc}). This curve has a similar form to a PV panel and any variables such as solar irradiance and module temperature will change the *I-V curve* as well.

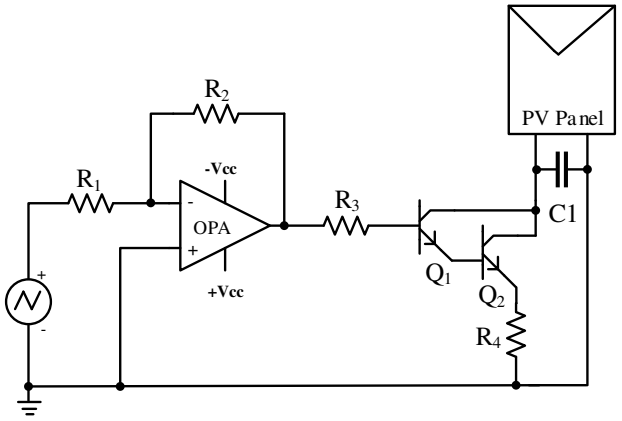
Consequently, it is necessary to characterize a PV panel accurately to obtain the correct parameters. To trace the *I-V curve* experimentally, the PV panel has to be exposed to a constant irradiance, and it must be connected to a variable resistance in order to measure the current and the voltage. In Maia (2017), it was realized an analysis of characterization methods and their parameters, such as: costs, accuracy, capacity for power processing, specific knowledge and performance. In this paper, the electronic load method was the better for this purpose.

This way, in this expanded abstract an electronic load method was used. Besides that, it presents the circuit to *I-V curve* characterization and its operation, describing its design and structure. Lastly, the results are compared with the curve that is provided by the PV panel manufacturer.

2 METODOLOGY

The circuit of electronic load is represented in the Figure 1. Their three main stages (signal generator, amplification stage and transistor stage) are connected with the PV panel.

Figure 1 – Characterizer topology.

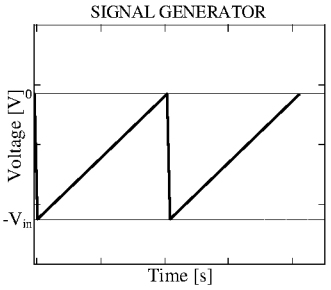


The circuit correct operation depends directly of the parameters sizing. The first stage gives a ramp waveform; the second stage has an operational amplifier. In the last stage is used a darlington transistor.

2.1 Signal Generator

The signal generator is responsible to insert the input signal. The general form of the wave is presented in the Figure 2, where V_{in} represents the peak voltage value.

Figure 2 - Input signal of the characterizer.

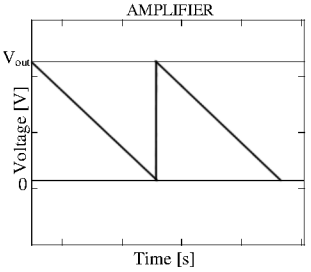


2.2 Amplification Stage

For that the transistor works correctly, the signal of its input must be a ramp waveform. Therefore, it was used an inverter operational amplifier, that the output voltage is given by (1), and is shown it in Figure 3.

$$V_{out} = -V_{in} \cdot A \qquad (1)$$

Figure 3 - Voltage after the operational amplifier.



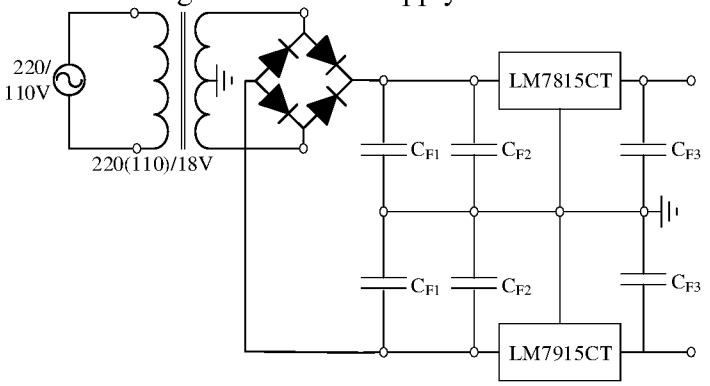
The operational amplifier (OPAMP) used was the LM741, because of linear characteristic and the frequency that was used is low. The gain of the circuit is given by (2).

$$A = -\frac{R_2}{R_1} \qquad (2)$$

Where, R_1 and R_2 are electrical resistances represented in Figure 1. For this project, the gain was established in six, and was chosen values where R_1 is 1.1 kΩ and R_2 is 6.6 kΩ.

For the OPAMP, it is necessary a symmetrical power supply, which circuit is represented in the Figure 4.

Figure 4 - Power supply circuit.



The parameters of the power supply are shown in the TABLE 1.

TABLE 1 - Power supply parameters

Description	Value
Filter to electronic capacitor	C_{F1} = 1.1 mF
Filter to polyester capacitor	C_{F2} = 10 ηF
Ripple rejection filter	C_{F3} = 1 µF

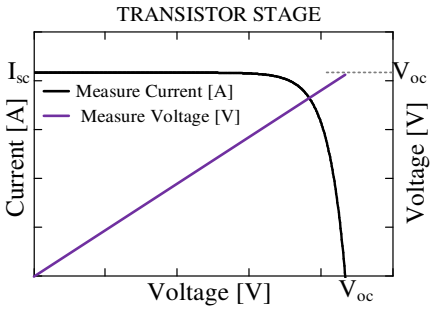
2.3 Transistor Stage

In this stage, there is a small variation on the transistor's base, because of that, the current that flows in the collector to emitter will vary as well.

Initially, the transistor current is maximum, because the input voltage is -V_{in}, and it is operating as a closed switch. Consequently, the photovoltaic panel is on its short circuit condition (I_{sc}).

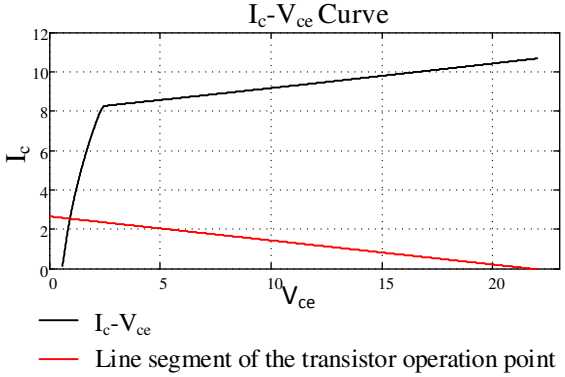
On the other side, when the current of the transistor is zero, the input voltage is also zero; the transistor is operating as an opened switch. In these conditions, the PV panel is on the open circuit conditions (V_{oc}). For the others values on the input curve, it is obtained the others point of the curve, as is demonstrated on Figure 5.

Figure 5 - Theorectical I-V curve of the photovoltaic panel



For that the project works, it is important that the transistor operate in its linear region, because of that, the resistances R_3 and R_4, Figure 1, are designed for this. This way, the design of R4 is obtained from the collector current (I_c) per collector-emitter voltage (V_{ce}) curve. The test was made with the transistor (TIP100) through the MULTSIM software, where the result is shown in Figure 6.

Figure 6 - I_c-V_{ce} curve of the TIP100.

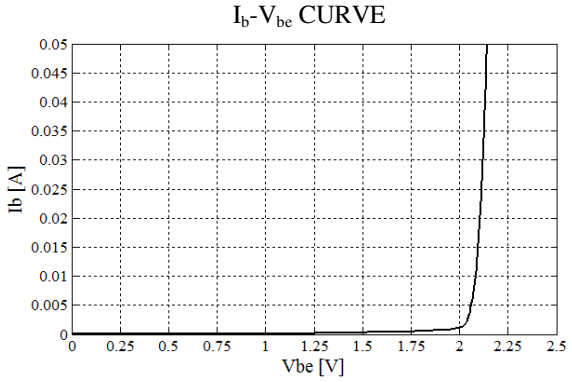


The intersection point of I_c and V_{ce} is used on (3).

$$R_4 = \frac{V_{oc} - V_{ce}}{I_c} \approx 8\Omega \qquad (3)$$

Besides that, to the R_3 design it is necessary trace the base current (I_b) and the base-emitter voltage (V_{be}) curve. The procedure is similar to R_4, and the results are shown in Figure 7.

Figure 7 - I_b-V_{be} curve of the TIP100.



The V_{be} voltage was defined 12V, and trough (4), it is possible calculate R_3.

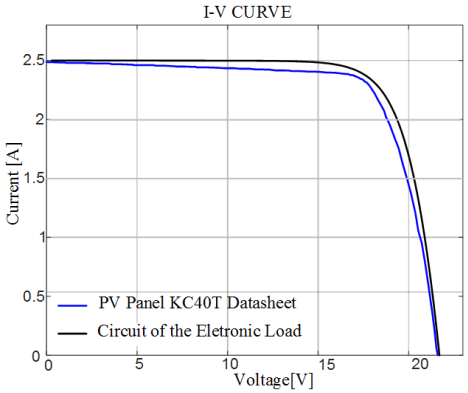
$$R_3 = \frac{V_b - V_{be}}{I_b} \approx 620\Omega \qquad (4)$$

3 RESULTS and DISCUSSION

The first version of the prototype to trace the *I-V curve* has two parts made in a printed circuit board (PCB), one to the main circuit of the Figure 1, and other to the power supply. The main circuit has connection to a function generator, to the power supply and to the PV panel. The first version was designed to the PV panel KC40T, according to its current level.

Also, it was made a simulation on PSIM software with the circuit of the Figure 1 and the panel physical model available on this software was used. The simulation results were compared with the *I-V curve* provided by the panel manufacturer, as shown in Figure 8.

Figure 8 - Results of the simulation



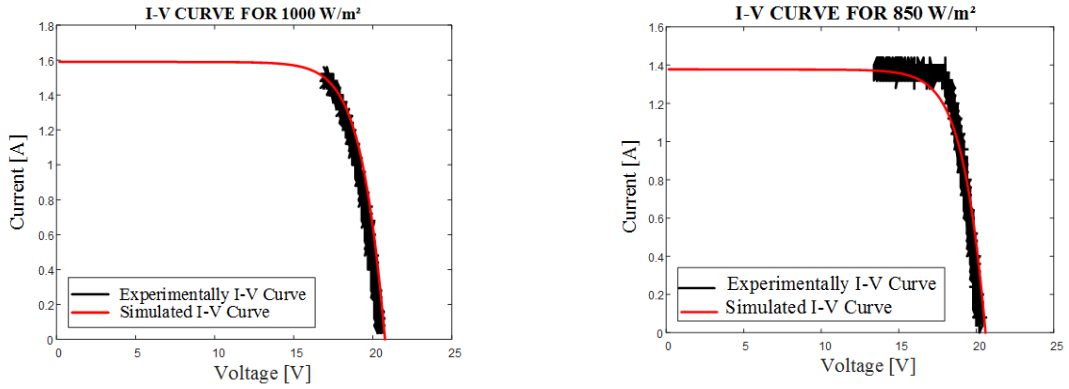
After the simulation, the prototype was built on PCB and is showed in Figure 9.

Figure 9 - PV panel characterizer prototype



The prototype tests were made in two irradiance conditions for 1050 W/m^2 in Figure 10 (a) and for 850 W/m^2 in Figure 10 (b). Besides, it was used the PV panel KC40T and, during the tests, the panel temperature was approximately 30ºC.

Figure 10 - PV panel characterizer results



(a) (b)

4 FINAL CONSIDERATIONS

Trace *I-V curve* experimentally is very important, because contains the characteristics of PV panel. It is used to get the maximum power point, that is a specific current and voltage values where is possible to extract the higher power of a PV panel. The curve also can be used to see if the PV panel has some damage, and any parameter alteration will reflect on this curve.

The simulation results are satisfactory, comparing with the datasheet points the curves are very close, the first part of the curve, before the maximum power point, there is a divergence because the physical model of the software is not able to represent the real comportment of the PV panel. In addition, the parameters used in the second part of the PV curve are an approximation, there were calculated by iterative methods.

The PV panel characterizer was able to trace the *I-V curve* experimentally before the maximum power point, because the panel voltage has not presented many variations. It can be observed that the curve was more alike with the simulated when the irradiance was higher; however, the voltage changed more with the lower irradiance. For a future work, it can be studied how to vary the voltage for values under the maximum power point.

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