ISSN 1870-4069

Development of the Electronic System for Obtaining the I-V and P-V Curves of Photovoltaic Module Using a Personal Computer

Jaime Vega Pérez[1], Blanca García[2], Saúl Vega Pérez[1]

[1] Instituto Politécnico Nacional,
Escuela Superior de Ingeniería Mecánica y Eléctrica, Ticomán,
Mexico

[2] Instituto Politécnico Nacional,
Centro de Estudios Científicos y Tecnológico 1,
Mexico

jvegap@ipn.mx, svega@ipn.mx, bgarcia16@ipn.mx

Abstract. The test, construction and design of an electronic system in order to measure the electrical characteristic curves of the photovoltaic (PV) module is reported, this electronic system reflects toward the PV module a variable resistance, sampling and capturing the PV module current and voltage, after using software the current and voltage signals are process in order to determinate the power, and also the PV module current- voltage and power voltage curves are gotten, This information is used for engineers who design PV systems to supplies electrical energy from sun energy to whatever equipment, the electronics circuit was made using electrical and electronics devices bought in México. Experimental results were done with 20 W. PV modules manufactured in CINVESTAV Mexico.

Keywords: Electronic system, photovoltaic module.

1 Introduction

The PV module is an electronic device which transform the visible light into direct current electrical energy, its output power depends of its area, incident light level, efficiency but it is reduced for temperature increase [1]. The PV module can be represented for its equivalent circuit (Fig. 1), considering its electrics parameters of resistance serial (R_s), parallel (R_f), link current throw (I_0) rectifier diode, generated current (I_g)' output current (I_c) and output voltage (V_c) all of them are showed in Fig. 1.

From Fig.1 electric circuit, applying the Kirchhoff Laws, the equations of output current and power of the PV module are obtained [2], where T is the temperature and K is Boltzmann constant:

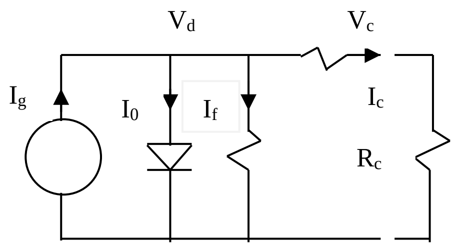

Fig. 1. PV module electric diagram.

$$I_c = -I_0 \left[e^{\frac{q(V_c + I_c R_s)}{KT}} - 1 \right] + \frac{I_c R_s + V_c}{R_f} + I_g, \quad (1)$$

$$P_c = V_c \left[I_g - I_0 \left(e^{\frac{q(V_c + I_c R_s)}{KT}} - 1 \right) - \frac{I_c R_s + V_c}{R_f} \right]. \quad (2)$$

When equations (1) and (2) are solved changing the values of output voltage V_c since the open circuit condition to short circuit condition, then all the values of power and voltage are obtained. When the current, voltage and power values are located in Cartesian coordinate system, then the current-voltage (I-V) and power –voltage (P-V) curves of the PV module are gotten (Fig. 2).

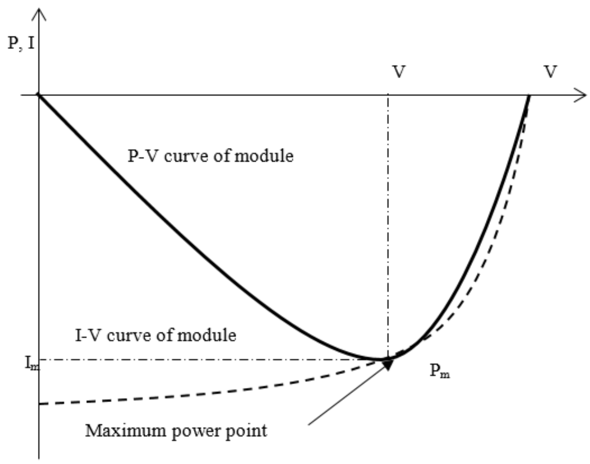

Fig. 2. I-V and P-V curves of PV module.

From Fig. 2 it is observed that the PV module has only a maximum power point, but in open circuit and short circuit conditions, the output power supplied by PV module is zero.

The most of PV modules are composed by 36 PV cells, they are connected in serial [4], its open circuit voltage is approximately 19 V, It is important to indicate that if the module temperature increases then its output voltage and power decrees [3], reported experimental results indicate the PV module temperature increases around 1.75 times than the local environmental temperature [2].When PV module working temperature is greater than 25°C, its output power and voltage start decreasing, therefore it is necessary to measure on the installation place its Current- Voltage and Power-Voltage characteristic curve and also to measure its output current and voltage in order to determinate the power, but on remote place there is not electrical energy. Therefore it is necessary to design an interface electronic system to be connected between PV module and a laptop, which collects the data of current-voltage of PV module and then the laptop process the electronic information in order to determinate the PV module output power. In addition, the PV module power – voltage and current voltage are plotted and displayed for the laptop. The technical information gotten of the PV module is useful for the design engineer.

Some researchers have developed electronic systems in order to locate the power of PV modules. Henry Shu-Hung Chung et al. [5], detected the maximum power point of the solar panel connecting a pulse width modulate (PWM) and a converter direct current to direct current (DC/DC) between solar panel and battery. Miguel Goncalves Wanzeller et al. [6] developed a Current control loop for the tracking of maximum power point supplied by photovoltaic array, located the maximum power of the solar array, using a three phase static direct current converter to alternate current (DC/AC), but he did not consider the temperature. Also The PV module maximum power can be located using and capacitive impedance [7].

In this work, we developed a theoretical and experimental method to design an analogical and digital electronic system using a micro controller and laptop computer to obtain the current–voltage (I-V) and power – voltage (P-V) curves of the PV module, the equipment can be used to measure PV modules in the installation place.

2 Proposal

The developed electronic system is integrated for: Drive circuit to Power MOSFET transistor, sensed electronic circuit of current (I) and voltage (V), two amplifier stages, microcontroller Arduino, synchrony circuit generator of triangle waveform, and laptop computer (Fig. 3).

The designed electronic system starts when the PV module is in open circuit condition, the lap top send to micro controller 5V pulse, then the Arduino send to analogue voltage starting since 0 V to drive circuit and this activates to MOSFET power transistor , which reflex variable resistance to PV module, then The PV module output current goes into the power transistor, at the same time, the current and voltage are sensed, amplified and sent to laptop PC throw microcontroller, The PC storage 500 samples of current and voltage during the process and detect when the PV module reach the short circuit condition, in this moment send 0V to drive circuit and power MOSFET transistor is turned off, the PV module goes back to open circuit condition. The computer storage all samples of current and voltage, after the laptop process the current and voltage electrical signals and obtain the power. Finally the current - voltage and power - voltage curves of the PV module are plotted. And we can see all the values of power, voltage and current variables and the characteristic curve of the PV module.

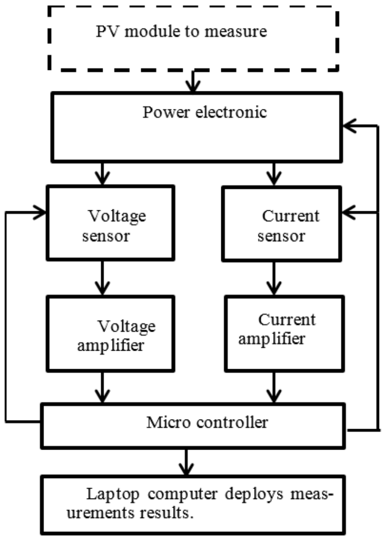

Fig. 3. Block diagram of electronic system designed.

3 Software Design

For accessing the voltage and current signals, an Arduino electronic card was used between the developed electronic circuit and the PC, the program was developed using software, with the following logical. The voltage signals were processed using Matlab software with the laptop PC, an Arduino hardware, controlled for the PC, was used in other to capture the electrical signal of current and voltage from PV module and this is transferred to laptop computer, the which process the electrical signals and determinate the characteristic curve of the PV module. The software was designed guessing the following diagram (Fig. 4).

4 Electronic Design

The first stage designed was the power driver circuit (Fig. 5), using MOSFET power transistor [8] connected at two operational amplifiers to get output voltage (V_o) linearity as function of input voltage (V_i) of operational amplifier, the LM308 integrate circuit was used, this circuit is coupled at the PV module to drain its current I_m since open circuit to short circuit. Also triangle voltage generator was designed using CI555

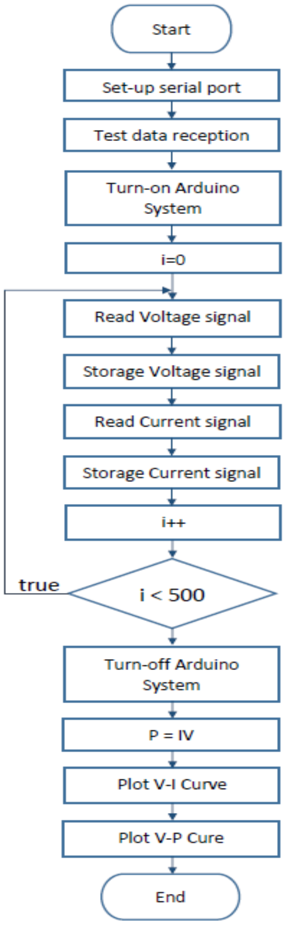

Fig. 4 Fluid diagram of the software.

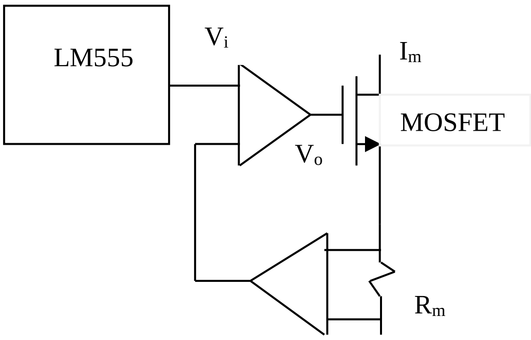

Fig. 5. Blok diagram of power driver circuit.

The PV module current (I_m) is sensed with R_m obtaining analogue voltage signal and it is amplified using a difference amplifier [9] whose output voltage V_{Im} for full scale is 5 V, the PV module voltage (V_m) is attenuated with an inverter amplifier. The inverter amplifier adapts the output voltage of PV module from 20 to 5 V and the difference amplifier adapts R_m voltage as current sample, and its output voltage change from 0 to 5 V. as operational amplifier were used the integrated circuit TL081. The Arduino micro controller card was used to couple the voltage signals from amplifiers with the computer, this controller was selected because has two analogic digital converters, memory unit can be programmed from the computer and is much cheaper (Fig. 6).

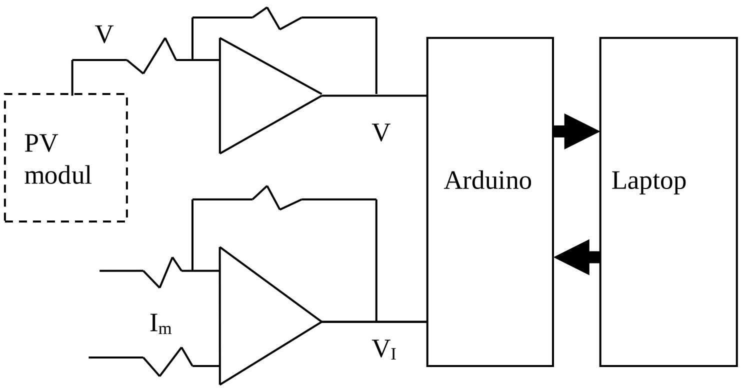

Fig. 6. Sense and amplification stage electronic circuit designed.

5 Implementation

All the electrical and electronic devices used to develop the designed electronic system were located in Mexico, also a printed circuit card was developed where the electronic devices were placed and connected, all resistances were of 0.25 W, BC 557 and CB547 were used for low voltage signal, the MOSFET power transistor N3055V was selected [10] because this drives up 6A and dissipates 90W and also a heat dissipater was used. The electronic system designed and developed (Fig. 7) was used together with an Arduino target UNO it has an ATMEGA328P microcontroller which has a 10 bits A/D converter. And also a laptop PC was used. The laboratory prototype is shown follow (Fig. 7).

6 Previous measurements results

The measurements were done using a 20 W PV module done in CINVESTAV-IPN México. The PV module current-voltage curve was gotten (Fig.8), it was placed at natural solar light, at 13:00 hrs. In a sunny day, also the illumination level was measured and its value was about 820W/m^2. The electronic system developed was tested measuring its waveforms to output generator of triangle waveform and current amplifier output (Fig. 7). The PV module current – voltage characteristic curve was measured, the results are in Fig. 8.

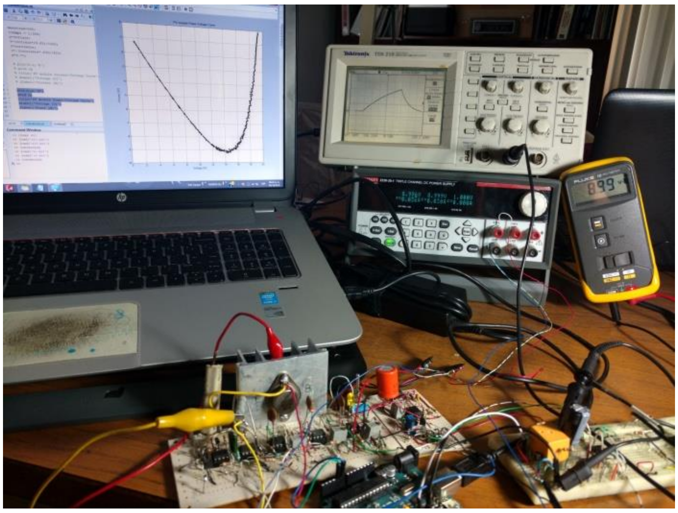

Fig. 7. Developed Electronic system and waveforms Measurement.

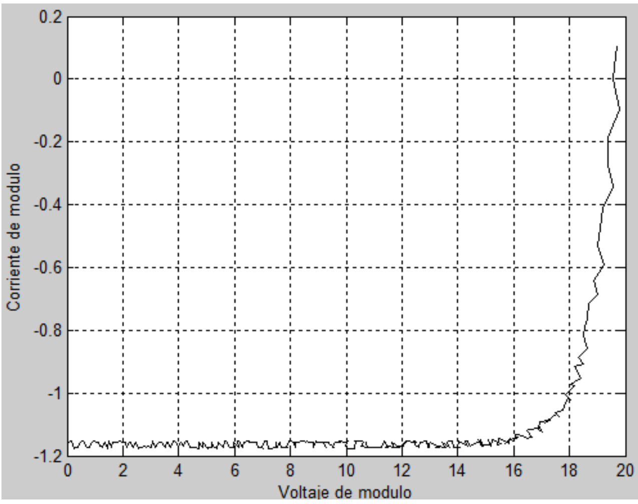

Fig. 8. Current-voltage curve of PV module measured with electronic system developed.

Also the PV module power – voltage characteristic curve was gotten, but in this case the measurement was done with 430W/m^2 of illumination level, the result is in Fig. 9.

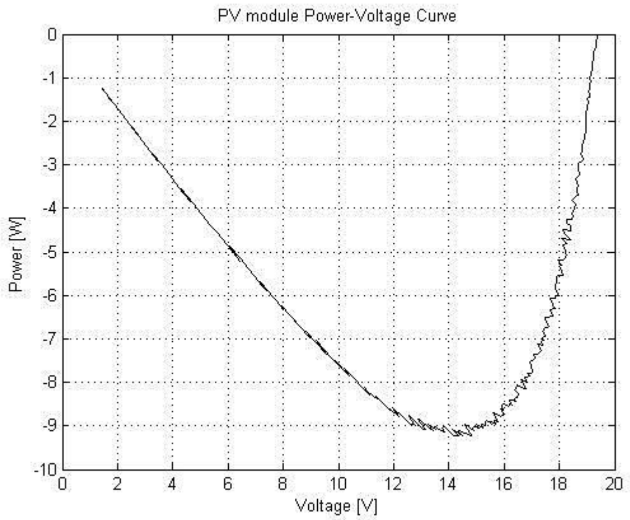

Fig. 9. PV module power–voltage curve gotten from developed prototype.

7 Conclusions

Upon experimental results, the electronic system developed and the software designed are working right, because the experimental results showed en Figs, 8 and 9 are agree with theoretical curves of the Fig. 2, all the electronic devices were located in México, the laboratory prototype developed is simple. Although a 20 W PV module was used, the measurement were done with real environmental conditions, then the illumination level was not with ideals conditions, then the power – voltage was measured when the level of illumination incident on the PV module was 430W/m^2, for this reason the measured power of PV module in this conditions was only a round 9.1 W.

Finally we can said, the developed electronic system to measure the PV module is very simple, easy and cheaper and this can be used in any place where we need to install photovoltaic systems.

Acknowledgements. The authors thank to the National Polytechnic Institute from México for its economic support with research project 20161548.

References

1. Jornar, B., Rekstad, J.: A photovoltaic/thermal (PV/T) collector with a polymer absorver plate experimental study and analytical model. Solar Energy, Vol. 72, No. 1, pp. 63–73 (2002)
2. Vega, J., Ponomaryov, V., Nino-de-Rivera, L.: Electronic system for power optimization of photovoltaic generator. International Journal of Electromagnetic Waves and Electronic Systems, No. 7-8, T. 8, pp. 12–15 (2003)

3. Kurokawa, K., Ikki, O.: The Japanese experiences with national PV System. Solar Energy, Vol. 70, No. 6, pp. 457–466 (2001)
4. Bazilian, M., Leenders, F., Van Der Ree, B., Prasad, D.: Photovoltaic cogeneration in the built environment, Solar Energy, Vol. 71, No. 1, pp. 57–69 (2001)
5. Shu-Hung, H., Tse, K. K., Wui, S. Y., Mok, C. M., Ho, M. T.: A novel maximum power point tracking technique for solar panels using a SEPIC or Cuk converter. IEEE Transactions on Power Electronics, Vol. 18, No. 3, pp. 717–724 (2003)
6. Goncalves, M., Nazareno, R., Alves, C., Viana da Fonseca Neto, J., dos Santos, A.: Current control loop for tracking of maximum power point supplied for photovoltaic array. IEEE Transactions on Instrumentation and Measurement, Vol. 53, No. 4, pp. 1304–1310 (2004)
7. Vega, J., Ponomaryov, V. I.: Maximum power detection electronic circuit for photovoltaic module. International Journal of Telecommunications and Radio Engineering, Vol. 56, No. 1, pp. 126–134 (2001)
8. Razavi, B.: Design of Analog CMOS Integrated Circuits. McGraw Hill (2001)
9. Kagali, M., Randjelovic, Z.: Auto-zero differential difference amplifier. Electronics Letter, Vol. 36, 13(8), pp. 695–696 (2000)
10. Jai, P., Grawal, A.: Power electronic systems theory and design. Prentice Hall, U.S.A. (2000)