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Software for measuring the characteristics of photovoltaic panels

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This paper presents the design and the development of specialized software, by which the characteristics of a photovoltaic panel can be tested and analyzed. The software controls a hardware module, which implements the electrical load of a photovoltaic panel and monitors its voltage. The values, measured by the hardware module, are transmitted to a PC via a serial interface. Then, these values can be visualized in a graphic form by the software, which allows the plotting of the volt-ampere and the power-volt output characteristics of the photovoltaic panel. The elaborated software enables us to set the parameters of the study: initial current and the current increment steps. The measured parameter values are recorded as PC files, allowing subsequent visualization and examination of data.

Keywords: photovoltaic solar panel, microcontroller programming, photovoltaic (PV) panel characteristics

INTRODUCTION

In recent years increased interest is observed in implementing photovoltaic systems for electrical energy production. At present renewable energy sources are becoming a larger share of the energy systems. For these two reasons the need to develop new technologies for testing and monitoring photovoltaic sources arises. Major indicators of the quality of any photovoltaic source are its I-V (Current vs. Voltage) and P-V (Power output vs. Voltage) characteristics, which often need experimental determination [1, 2]. Current vs. Voltage and power output characteristics are presented on Fig.1.

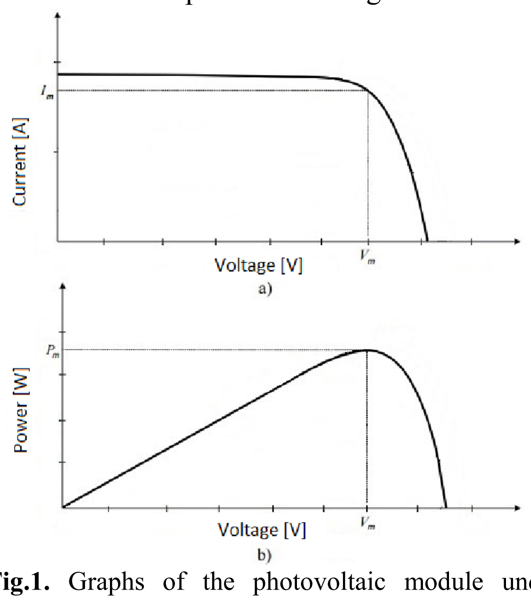

Fig.1. Graphs of the photovoltaic module under different temperature and illuminance: a) *Current vs. Voltage* I-V characteristic; b) *Power output vs. Voltage* P-V characteristic of the photovoltaic panel

The basic characteristic points of the I-V and P-V characteristics are: maximum current at voltage 0V of the photovoltaic source (short circuit current I_{sc}), maximum voltage of the photovoltaic source at current 0A (voltage at open circuit V_{oc}) [3]. For each point of the I-V curve, the current and the voltage give information about the power output under the corresponding conditions [4]. The point of maximum power (maximum power point MPP), which can be obtained, is achieved in those points of the characteristics, where the I-V has a maximum curvature.

The Fill-Factor is defined by formula (1):

$$FF = \frac{I_m . V_m}{I_{sc} . V_{oc}} , \quad (1)$$

where I_m is the rated current and V_m is the rated voltage. Usually the FF is used to shows how close a PV cell or panel is to the ideal case. [5]. These parameters allow to determine the status of a photovoltaic system and to detect failures in it. The main principle for experimental determination of the I-V curve is based on controlling the current flowing through the photovoltaic module and measuring its voltage. There are a number of methods for solving this task, in which controlling the load current through the photovoltaic module is accomplished by a variable resistor, capacitive load or electronic load [1].

This paper presents the design and development of specialized software, by means of which the I-V and P-V characteristics of photovoltaic panels can be experimentally determined. The software controls a hardware module, by which electrical loading of a

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photovoltaic panel is accomplished, continuously monitoring its voltage.

The hardware module for studying photovoltaic panels consists of a power supply block, a block for measuring the voltage of the photovoltaic module, a block for regulation and measurement of the current through the photovoltaic module, a PIC microcontroller (MCU), and a personal computer (PC). The block diagram of the hardware module is shown in Fig.2.

The microcontroller sends the values from the measurements to a personal computer, where the I-V and P-V characteristics are visualized in a graphic form by means of the especially developed for this purpose software.

The developed specialized software includes: software for a personal computer and control program for the microcontroller.

PC SOFTWARE FOR MEASUREMENT AND VISUALIZATION OF THE I-V AND THE P-V CHARACTERISTICS OF PHOTOVOLTAIC PANELS

The developed software is aimed at configuring the computer as a monitoring system for studying the I-V and P-V characteristics of photovoltaic sources, and also as an interface system for communication with the MCU microcontroller. The connection between the two devices is realized by means of a serial interface for communication (UART). The main user interface of the developed software is shown in Fig.3.

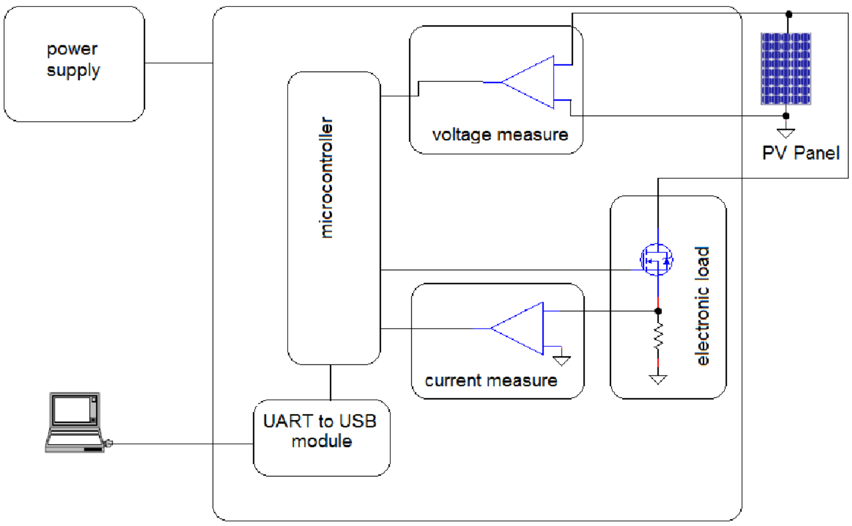

Fig.2. Block diagram of the hardware module

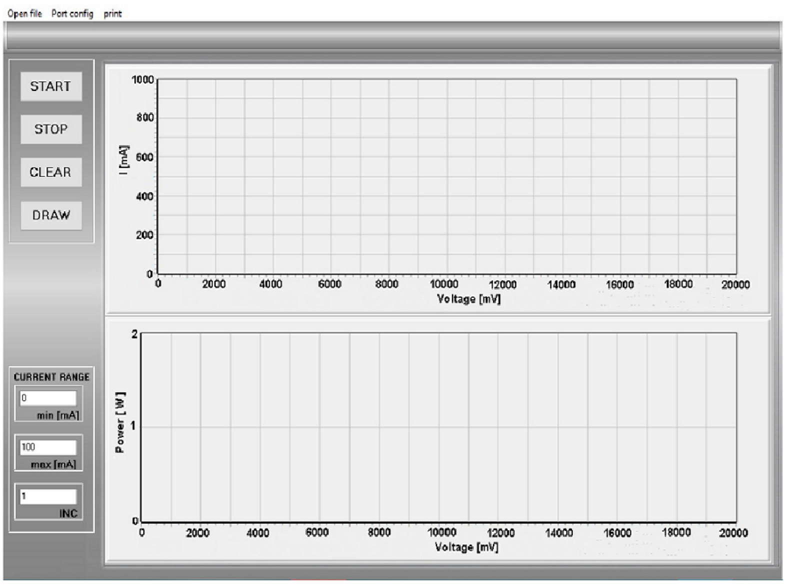

Fig.3. PC Software graphical user interface

The software sends commands to the microcontroller for measuring both the current and the voltage of the photovoltaic panel. The software receives the measurement data from the microcontroller, records them in a file, processes them mathematically and then displays them graphically. A possibility is envisaged to back up the measured voltage, current and power values in files of user's choice.

The developed software allows setting the basic parameters of the measurement: minimum value of the load current, maximum value of the load current, and step of increase of the current. There are fields in the main package of the user interface, where the corresponding values are introduced.The voltage of the photovoltaic panel is measured under certain conditions of illuminance. After the program has been started, the voltage at the terminals of the photovoltaic panel is first measured when there is no current flowing through the panel. Thus, the maximum voltage of the photovoltaic source is determined (voltage at open circuit V_{oc}). After that from the personal computer the value of the current to flow in the load circuit of the panel is sent. The microcontroller receives this value and sends it to a digital-to-analogue converter (DAC), which controls an electronic load, implemented by a MOSFET transistor. Immediately after establishing the predetermined current, the microcontroller starts measuring both the voltage of the photovoltaic panel, and the value of the current in the load circuit of the photovoltaic panel.

The accuracy in setting the value of the current in the load circuit depends on a number of parameters, including the steps of measuring and the temperature at which the device is situated. The current flow increases the temperature of the electronic components, which make up the electronic resistance. This can lead to occurrence of a difference between the digitally set value of the current by a DAC and the real value of the current, flowing in the circuit. In order to reduce this effect it is necessary to use components with a small temperature coefficient and to reduce the measuring time.

Since the temperature dependence cannot be entirely avoided, it is envisaged that the value of the current in the load circuit is continuously measured by an ADC.

After completing the measurements, the microcontroller sends the values to the personal computer. By means of the developed software, the measurements values are visualized in a graphic form and recorded in a file. This is repeated until the value of the current in the load circuit of the photovoltaic panel reaches the preliminary set value of the maximum current in the field of the main software panel.

The possibility to back up all measurements is of great significance as they can be visualized and analyzed afterwards. This is important when studying photovoltaic sources for long periods of time or when carrying out quality control of a series of copies. A possibility for printing the obtained graphs on paper is envisaged.

A generalized flow chart of the developed software is given in Fig.4.

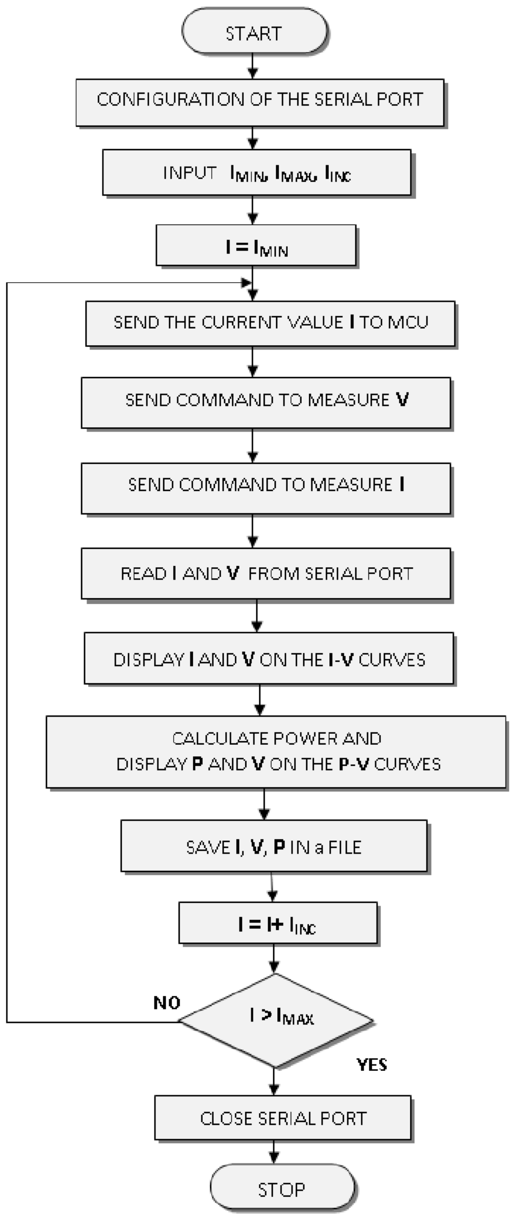

Fig.4. PC Software Flow chart

MICROCONTROLLER CONTROL PROGRAM

The microcontroller, which is used in the present development, is an 8-bit CMOS microcontroller PIC16F876A. Its clock frequency is 8 MHz, which can provide 2 MIPS. The communication between the microcontroller and the personal computer is realized by means of a series interface UART and the USB port of the PC. A USB port converter FT232RL is used for the purpose. A DAC, generating an analogue signal, is connected to the SPI port of the microcontroller. Thus the current, flowing through the photovoltaic panel, is controlled. Port A of the microcontroller is programmed as an analogue input for the ADC. Channels 1 and 2 are used for measuring the voltage and the current. Fig.5 presents a generalized flow chart of the microcontroller control program.

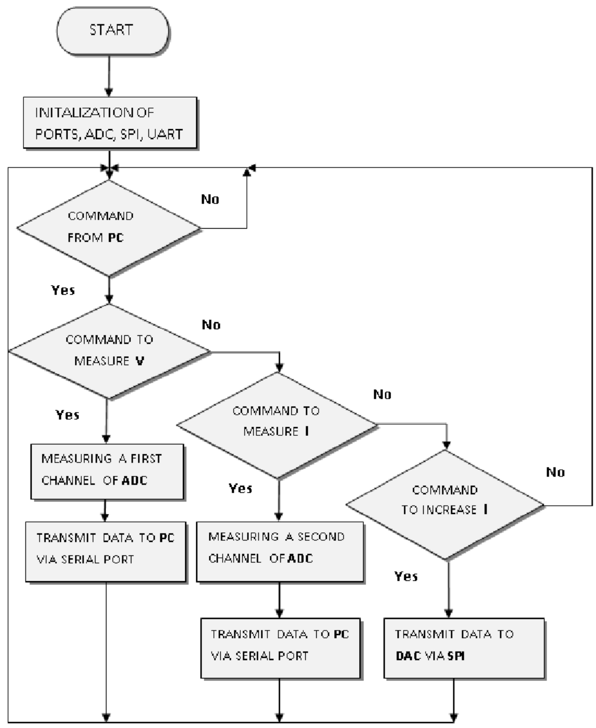

Fig.5. Microcontroller control program flow chart

EXPERIMENTAL RESULTS

Fig.6 and Fig.7 present experimentally obtained I-V and P-V characteristics of a monocrystalline silicon photovoltaic panel with maximum power of 5W at different illuminance levels and different surface temperatures of the studied photovoltaic module. We performed outdoor experiments and the corresponding temperatures were measured by a MS8209 digital multimeter, while the illuminance levels were measured by a MS6612 Digital Light Meter. The obtained graphic dependences allow for a fast and easy definition of the basic parameters, summarized in Table 1.

Table 1. Basic parameters of a monocrystalline silicon photovoltaic panel with maximum rated power 5W

Illuminance [lx]	Short-circuit current Isc [mA]	Open-circuit voltage U [V]	Maximum power P [W]
78 000	145	17.1	1.62
115 000	258	17.5	2.15

The results show that together with increasing the light power, incident on the active area of the photovoltaic panel, the maximum electric power, which the panel can release toward the load, also increases. It is obvious that light intensity change influences the short-circuit current stronger than it influences the idle-run voltage. From Fig.6 it can be clearly seen that when increasing the temperature of the photovoltaic panel, the shape of the I-V characteristic also changes, what, in turn, leads to reduction in the Fill-Factor, compared to its value at lower temperature.

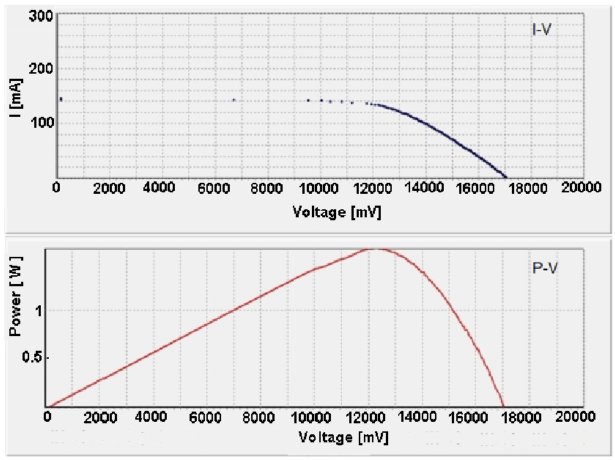

Fig.6. I-V and P-V characteristics of a monocrystalline silicon photovoltaic panel with maximum power 5W at illuminance levels of 115 000 lx and surface temperature of the studied photovoltaic module of 60° C

Similar experiments have been conducted for a monocrystalline silicon photovoltaic panel with rated power of 0.7W and the obtained I-V and P-V characteristics are presented in Fig.8 and Fig.9. The defined basic parameters of the photovoltaic panel are presented in Table 2. The tests show an increase in the electrical power output of the photovoltaic panel with an increase in solar radiation.

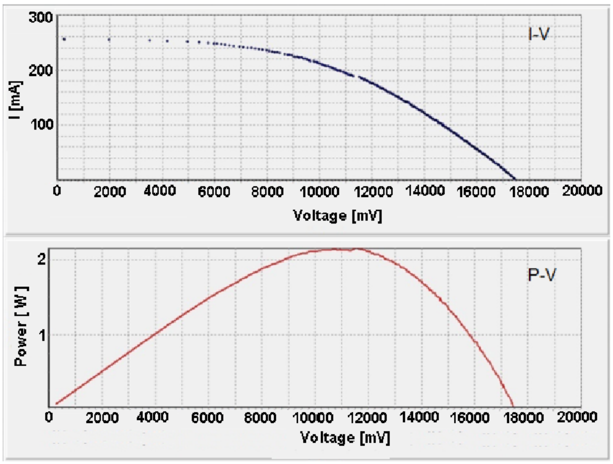

Fig.7. I-V and P-V characteristics of a monocrystalline silicon photovoltaic panel with maximum power of 5W at illuminance levels of 78 000 lx and surface temperature of the studied photovoltaic module of 28° C

Table 2. Basic parameters of a monocrystalline silicon photovoltaic panel with maximum rated power of 0.7W

Illuminance [lx]	Short-circuit current Isc [mA]	Open-circuit voltage U [V]	Maximum power P [W]
115 000	64	11.8	0.56
70 000	41	11.75	0.37

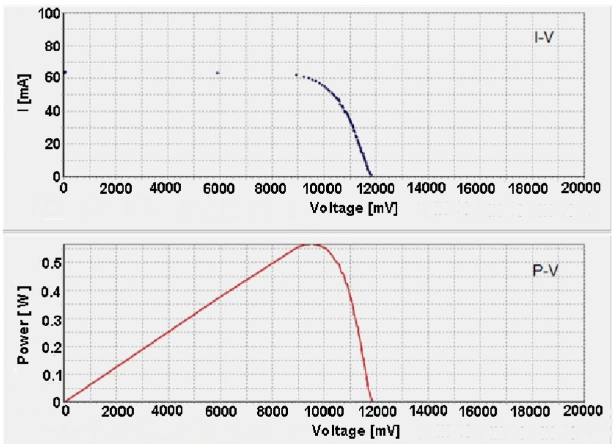

Fig.8. I-V and P-V characteristics of a monocrystalline silicon photovoltaic panel with maximum power of 0.7 W at illuminance levels of 115 000 lx and surface temperature of the studied photovoltaic module of 28° C

From the conducted experiments it can be concluded that the output power produced by the photovoltaic module depends mainly on solar radiation. Consequently, in order to achieve maximum efficiency of a renewable energy system, it is necessary to define the working point at which the photovoltaic system can provide maximum power of the load (maximum power point MPP). The location of this point depends on the solar radiation and the temperature of the panel.

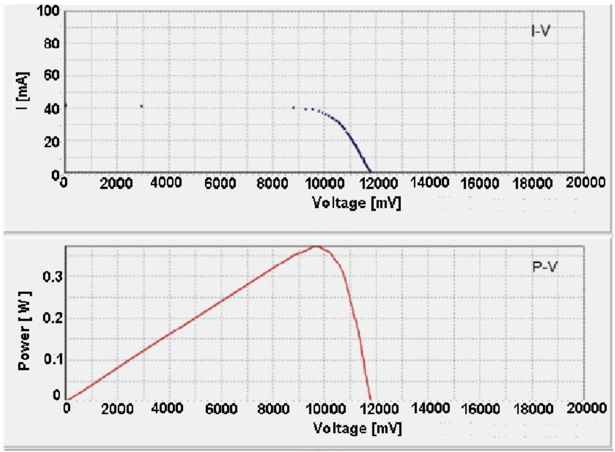

Fig.9. I-V and P-V characteristics of a monocrystalline silicon photovoltaic panel with maximum power of 0.7 W at illuminance levels of 70 000 lx and surface temperature of the studied photovoltaic module of 28° C

CONCLUSION

The developed software proposes a fast and easy solution for making a device for studying the parameters and characteristics of photovoltaic panels and modules. Modern easily accessible components and circuits are used for the hardware part, controlled by the developed software. The software can be successfully used for studying both individual panels and entire modules from photovoltaic systems.

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REFERENCES

1 E. Durán, M. B. Ferrera, J. M. Andújar, M. S. Mesa, I-V and P-V Curves Measuring System for PV Modules based on DC-DC Converters and Portable Graphical Environment, Industrial Electronics (ISIE), 2010 IEEE International Symposium, 3323 – 3328, (2010).
2 E. Durán, J.M. Andújar, J. Galán, M. Sidrach-de-Cardona, Methodology and Experimental System for Measuring and Displaying I-V Characteristic Curves of PV Facilities, Progress in Photovoltaics Research and Applications, 574-586, (2009).

3 Y. Hishikaw, Y. Tsuno, K. Kurokawa, Translation of the I-V curves of various solar cells by improved linear interpolation, 21st European Photovoltaic Solar Energy Conference, Dresden, Germany, (2006).
4 Y. Atia, M. Zahran, A novel system for photovoltaic solar cell test and characteristics measurements, ERJ Engineering Research Journal, Faculty of Engineering Minoufiya University, Vol. 32, No. 4, (2009).
5 A. Ndiaye, C. M. F. Kébé, P. Ndiaye, A. Charki, A. Kobi, V. Sambou, Impact of dust on the photovoltaic (PV) modules characteristics after an exposition year in Sahelian environment: The case of Senegal, International Journal of Physical Sciences, Vol. 8, 1166-1173, (2013).