

AUTOMATIC SYSTEM FOR DETERMINING THE CHARACTERISTICS OF A PHOTOVOLTAIC PANEL

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Abstract: One of the modern solutions to reduce pollution is the production of electricity from renewable sources such as solar energy using photovoltaic panels. Photovoltaic panels convert sunlight into electricity. To characterize a photovoltaic system, its real characteristics must be known. It is also desirable to test the photovoltaic panels after a period of time after installation in order to determine the evolution of the characteristics of the photovoltaic panel over time. This paper presents a system for the automatic determination of the power characteristics of a photovoltaic panel, thus being able to determine the maximum power point.

Keywords: photovoltaic, system, solar energy, power characteristics, data acquisition system

1. Introduction

If a photovoltaic cell is exposed to constant light radiation has a theoretical current-voltage characteristic as shown in Figure 1. The variation of the current-voltage characteristic of a commercial photovoltaic module depends on irradiance and temperature. Under standard test conditions [1] at a temperature T of 25°C , the panel is tested at a light intensity S of 1000 W/m^2 , 800 W/m^2 , 600 W/m^2 , 300 W/m^2 , resulting in current-voltage output characteristics of the photovoltaic cell shown in figure 1.

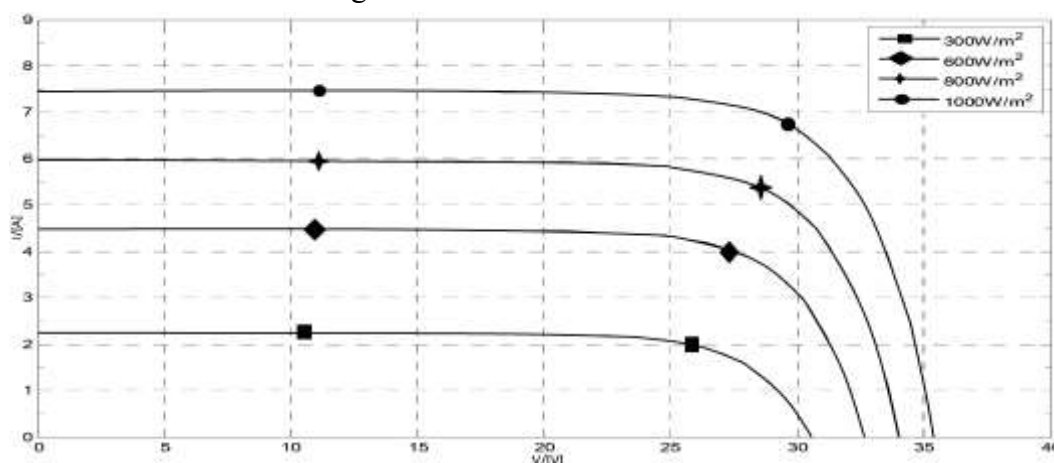


Fig.1. Current Voltage characteristic for different irradiation levels

There is a single point on the curve, called the maximum power point, at which the PV cell operates at maximum efficiency and produces maximum power output.

The photovoltaic power-voltage characteristic for four different irradiance levels is shown in figure 2.

It can be seen that, while the light intensity increases, an increase in the output power results.

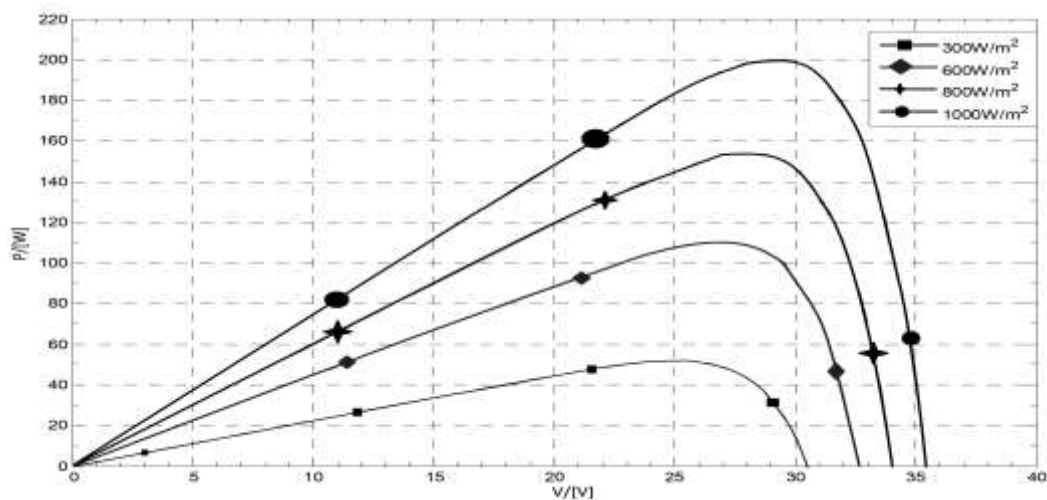


Fig.2. Power Voltage characteristic for different irradiation levels

Usually maker of the photovoltaic panel provides only the following characteristics:

- Maximum Power - P_{max} ,
- Voltage at P_{max} - V_{mp} ,
- Current at P_{max} – I_{mp} ,
- warranted minimum - P_{max} ,
- Short-circuit current - I_{sc} , Open-circuit voltage – V_{oc} ,
- Temperature coefficient of I_{sc} ,

Temperature coefficient of power but not the real current-voltage characteristics and power-voltage.

The determination of the current-voltage characteristics for a photovoltaic panel

The experimental drawing of the characteristics can be done by connecting to the photovoltaic panel terminals a resistance according to the block diagram in figure 3, resistance that can be adjusted from 0 (Short circuit) to a high value.

To obtain a large number of points per feature and to automate the measurement process requires a complex system. To obtain a variable load, electronic circuits based on MOSFET transistors can be used or, if a linear change in the load resistance is not required, a capacitor can be used that will be charged from the photovoltaic panel. Since the loading time is relatively short, a measurement system with a high acquisition speed is required.

2. The proposed system

The proposed system is based on the phenomenon of charging a capacitor to the voltage generated by the photovoltaic panel and the acquisition of voltage and current signals in order to trace the characteristics of the photovoltaic panel. For this, an automatic system has been implemented that discharges the working capacitor which it then connects to photovoltaic panel terminals. The system can make high-speed acquisition of circuit voltage and current and will transmit them to the software application at a rate of up to 20.000 measurement points/second. The block diagram of the system is shown in figure 3

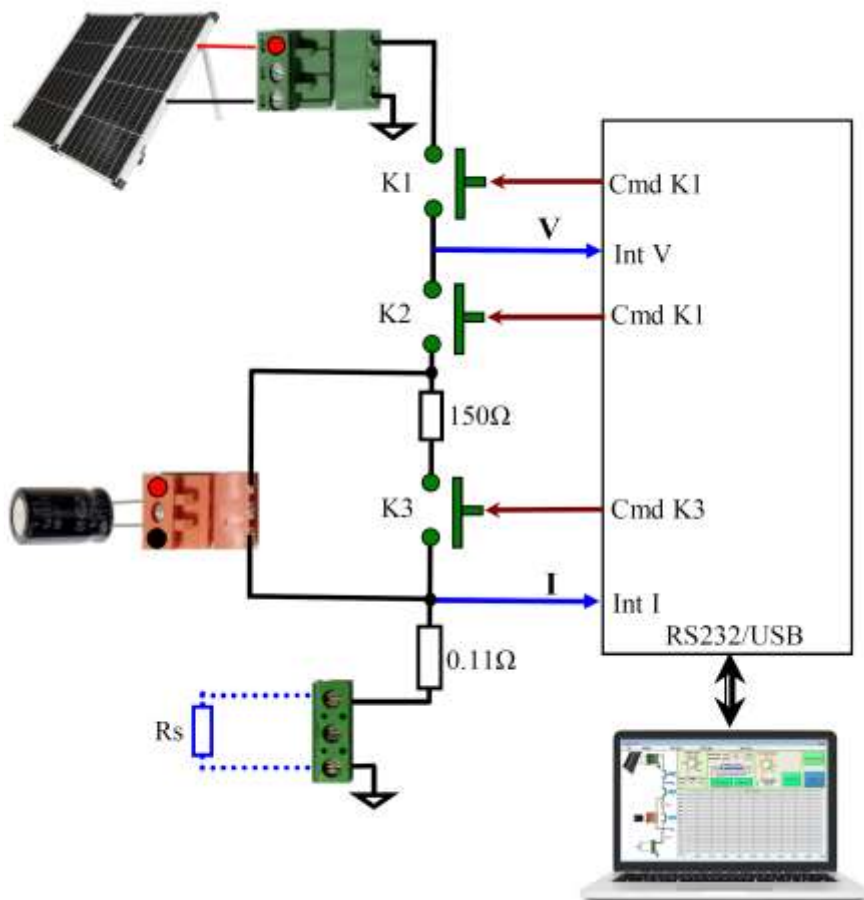


Fig.3. Experimental system

The system has three electronic switches that can be controlled independently. The role of these switches is:

- K1 connects the output of the photovoltaic panel to the test circuit,
- K2 connects the capacitor to the photovoltaic panel
- K3 discharges the capacitor

The way it works is as follows: initially all 3 switches are open. The closing command of switch K3 has the effect of discharging the capacitor across a 150Ω resistor for a specified period of time. Switch K3 is opened, switch K2 is closed, and the mode of acquisition and transmission of voltage and current readings is initiated which are displayed graphically. Switch K1 is then closed and the voltage and current will be displayed for a period of time or until the current drops to near zero. When the current drops close to zero, the acquisition mode stops and you can switch to automatic data processing tracking the desired features. The system is not equipped with automatic reading of temperature and light intensity, but these parameters can be entered manually from an independent system so that the acquired and saved data also contain this information.

The analog switches are made with MOSFET transistors, the control circuit being completely galvanically isolated from the control circuit. The datasheet of the electronic switch is shown in figure 4.

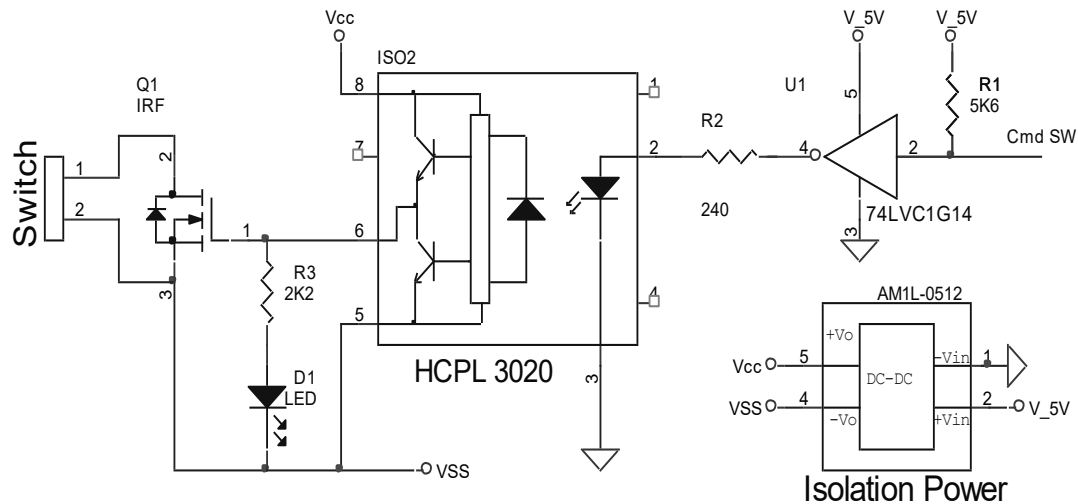


Fig.4. Proposed Switch

Two independent signal conditioning circuits made with the AD623 instrumentation amplifier with 2-stage gain adjustment and a precision adjustment for each stage were implemented for current and voltage reading. Thus the proposed system can be configured for a wide range of photovoltaic panels.

The command and communication system was implemented using the LGT8F328P microcontroller. LGT8F328P is a microcontroller similar to the Atmel AVR atmega328P used on the Arduino Nano, but with additional capabilities such as higher speed and has a higher resolution for converting analog signals and having a digital-to-analog converter as well.

LGT8F328P Parameter:

- The LGT8F328P enhances 8-bit RISC core, supports 16-bit digital operation expansion, and can run at a core frequency of up to 32MHz within the working range of 1.8V-5.5V;
- The LGT8F328P internal 32K bytes of FLASH program memory, 2K bytes of data SRAM, built-in control logic that simulates FLASH as EEPROM, part of the program FLASH can be divided into data FLASH space according to application needs, and EEPROM-like interface access is realized through the EEPROM controller ;
- The LGT8F328P integrates a wealth of analog peripherals, including 12-bit ADC, programmable gain differential amplifier, high-precision 1.024/2.048/4.096V internal reference voltage, 8-bit DAC and high-speed analog comparator; at the same time LGT8F328P also integrates commonly used digital Interface controller, supports multi-channel complementary PWM output and dead zone control ;
- The LGT8F328P architecture design is relatively new, and its peripheral functions are far stronger than that of the Atmega328P. In particular, the program encryption capability far exceeds Atmega328P.

An acquisition system was thus implemented that can achieve data transmission speeds of up to 1,000,000 b/s and acquisition rates of up to 70,000 samples/second. The realized

system is one that acquires 2 signals (voltage and current) and transmits up to 20,000 pairs of values / second. Each conversion is done with 12-bit resolution.

3. Software application

The software application controlling the switch and data acquisition system was implemented in LabWindows. The main working window is shown in figure 5.

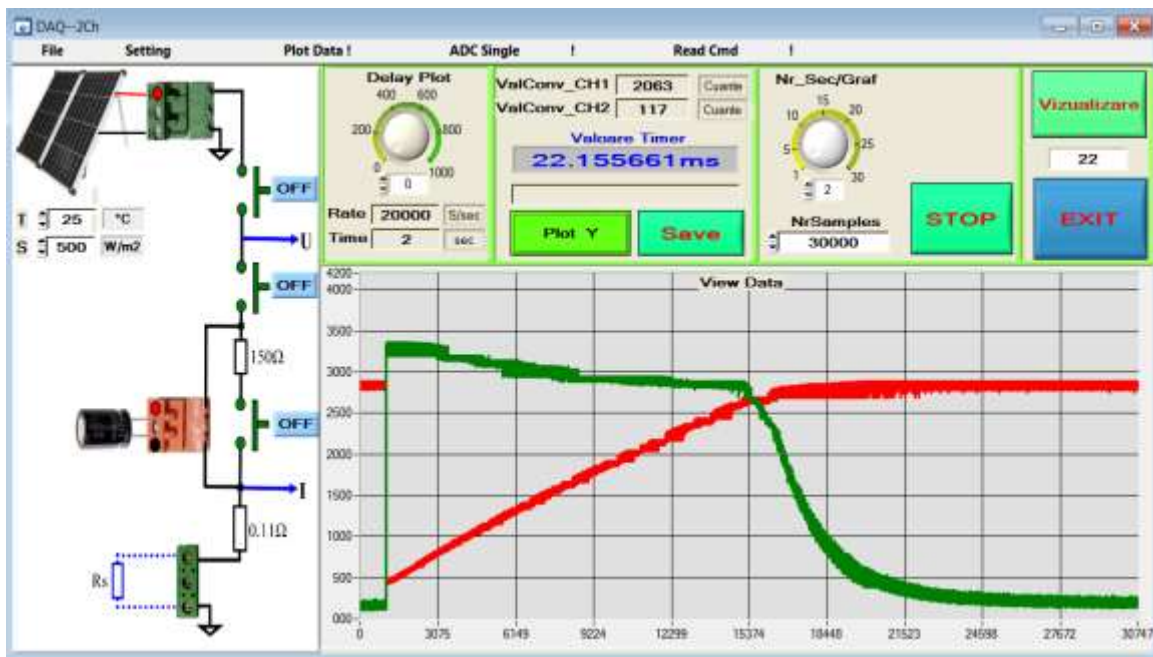


Fig. 5 Software application

The software application has the possibility of setting the communication by being able to set one of the 13 available serial ports and a transfer rate of up to 1,000,000 bits/second depending on the controller used. The set values are saved to a file and loaded automatically when the application is launched. It is also possible to set the number of bits for acquisition and display. The LGT8F328 performs 12-bit conversions and the Atmega328 performs 10-bit conversions.

Using the ADC_Single menu a single conversion can be made useful for communication testing or system calibration tests. There is also the possibility of reading the switches and their independent control in order to carry out tests and calibrations. The Delay_Plot button allows setting an acquisition rate of up to 20,000 pairs of voltage/current values per second. The application also allows setting the maximum number of points to be purchased.

The collected data is saved automatically. After the acquisition of the voltage and current signals, there is the possibility of additional data saving, plotting the current-voltage characteristic or switching to the data visualization and analysis application. Figure 6 shows the voltage and current signals acquired from a BP SX 30U photovoltaic panel.

BP SX 30U photovoltaic modules are part of BP Solar's SX module series, providing cost-effective photovoltaic power for DC loads with moderate energy requirements. With 36 multicrystalline cells in series, they charge batteries efficiently in virtually any climate. Typical commercial applications of these modules, which generate nominal maximum power of 20 watts and 30 watts respectively, include remote telemetry, instrumentation systems, security sensors, signals, and land-based navigation aids. The BP SX 30U are designed primarily for industrial use and other particularly demanding applications and have typical electrical characteristics [3]:

- Maximum Power (Pmax) 20W 30W
- Voltage at Pmax (Vmp) 16.8V 16.8V
- Current at Pmax (Imp) 1.19A 1.78A
- Warranted minimum Pmax 18W 27W
- Short-circuit current (Isc) 1.29A 1.94A
- Open-circuit voltage (Voc) 21.0V 21.0V
- Temperature coefficient of Isc $(0.065 \pm 0.015)\%/^{\circ}\text{C}$
- Temperature coefficient of Voc $-(80 \pm 10)\text{mV}/^{\circ}\text{C}$
- Temperature coefficient of Power $-(0.5 \pm 0.05)\%/^{\circ}\text{C}$

For additional analyses, you can run the analysis and visualization application shown in figure 8. The application allows filtering signals, zooming in on the areas of interest, displaying the power voltage characteristic to determine the maximum power point.

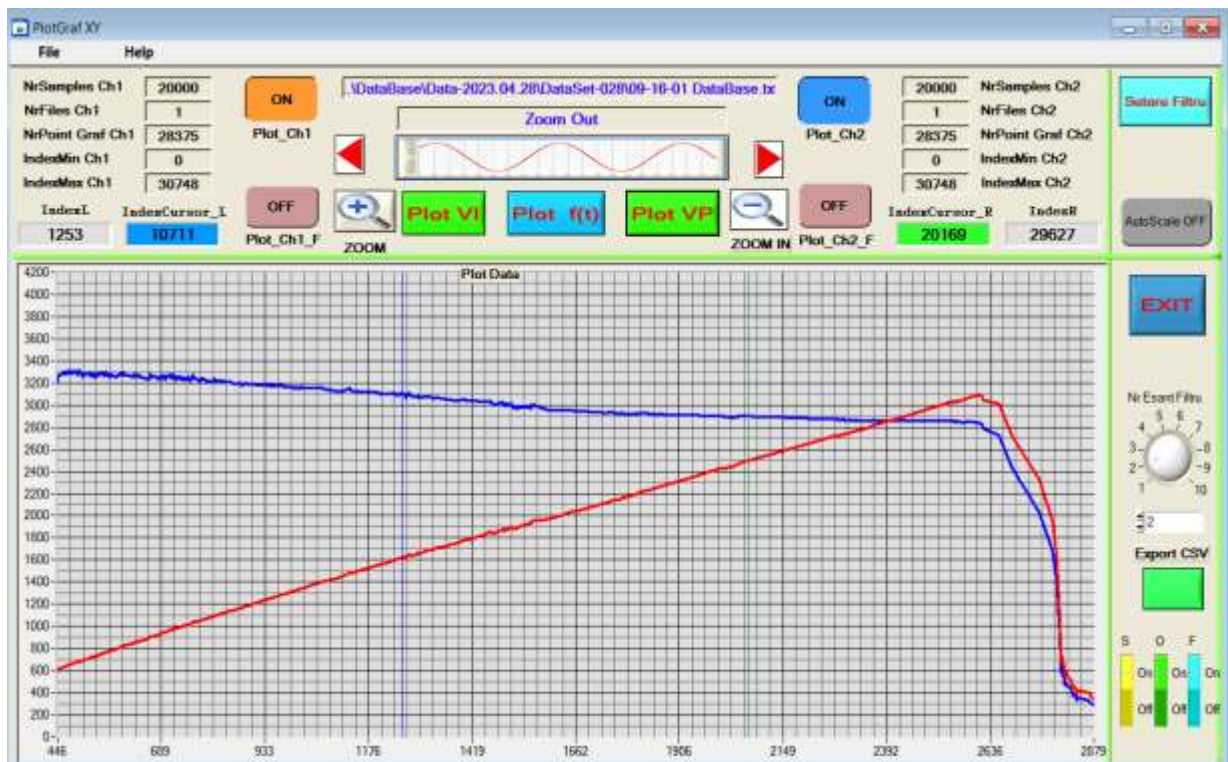


Fig. 6 Analysis and processing software

4. Conclusion

The proposed experimental system implements a simple method for testing the characteristics of a photovoltaic panel. Following the practical experiments carried out, it was found that the obtained results are in perfect agreement with the theoretical notions, which leads to the conclusion that the chosen method is one that can be used in practice.

The system has the automation of data ordering and acquisition operations, real-time visualization of the acquired data, data saving and the possibility of further data analysis.

The system can be upgraded by adding a temperature sensor and a solar radiation sensor to automatically measure the 2 values. Also, the visualization application can be modernized by implementing several types of features that can be drawn as well as by the possibility of exporting these features for Excel.

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