STAND-ALONE SYSTEM ON RASPBERRY PLATFORM FOR MEASURING THE PARAMETERS OF PHOTOVOLTAIC MODULES IN REAL CONDITIONS

[1, 2]Gaevskii A., Doctor of Phys. Math. Sci., Professor, [1]Ivanchuk V., PhD student
[1]Igor Sikorsky Kyiv Polytechnic Institute, [2]Institute for Renewable Energy NAS of Ukraine

Introduction. The pilot stand-alone system is developed for determining photovoltaic modules parameters (PVM). This system is designed on the Raspberry Pi microcomputer and allows to measure the V-I characteristic and determines the main PVM parameters during several seconds in field conditions. These parameters referred to the one-diode PV cell equivalent circuit characterize the current operation characteristics of PV modules: their real maximal power, electrical losses and degradation degree.

Keywords: *PV module, V-I characteristic, equivalent circuits, determination of PV module parameters.*

The results of the research. The efficiency of photovoltaic modules (PVM) as part of PV plants significantly depends not only on the level of solar radiation, temperature, but also on the ageing process during operation under real conditions. The result of PVM ageing under the influence of temperature fluctuations, high humidity, and intense irradiation is the degradation of their electrical characteristics, and a decrease in efficiency [1]. The system for measuring the actual parameters of the PVM can provide valuable information about the state and service life of arrays of PV modules, optimizing the operating modes of the photovoltaic power plant in the power system. The main parameters of the PVM such as open-circuit voltage Voc, short-circuit current Isc and maximum power point Vm, Im are measured by manufacturers under standard test conditions (STC). But to describe the current state of the PVM, especially after their long-term operation, it is necessary to know a more complete set of parameters that must be obtained directly at the PV plant. Under real operating conditions with varying radiation, PVMs rarely perform as well as they can under STC conditions, so PVM performance deviates from manufacturer specifications frequently. In this regard, an urgent task is the development of appropriate measuring systems, which include both hardware for operational measurements in the field and algorithms for processing measurement results and obtaining PVM parameters.

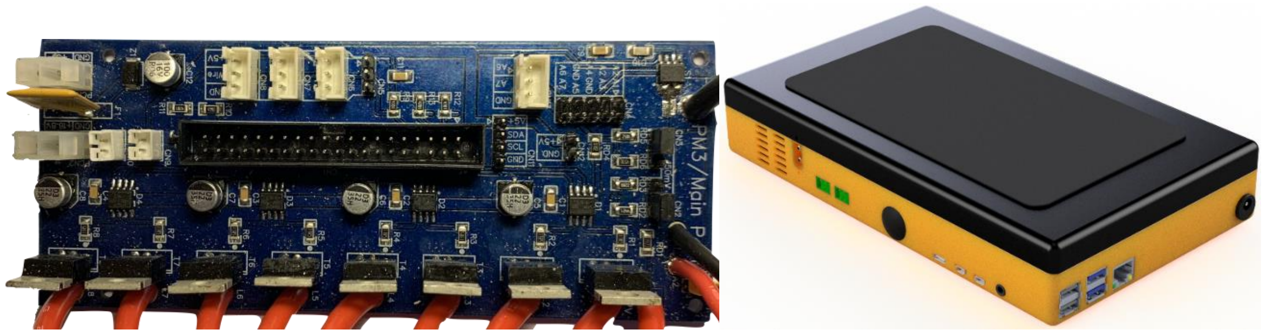
To date, PVM testing systems have been implemented on various microcontroller platforms [2]. In this work, the design and software of the measuring system was developed on the Raspberry Pi microcomputer, which makes it possible, at time intervals of several seconds, to autonomously process the experimental data and calculate the parameters of PVM in field without using a computer and a web server.

In this work the I-V curve tracking is achieved through the use of two methods: a capacitor charge cycling and a variable resistive load. These methods are realized on the base of Raspberry Pi microcomputer which provides the automatic data acquisition and calculates the PV parameters according to developed algorithm for a time comparable to the tracking time. Due to the short scanning time of the full I-V characteristic (less than 1 s), the level of solar radiation and the temperature of the module during the measurement could be considered unchanged. The elements of the stand-alone measuring system designed in our work are shown on Fig.1.

The measured data are processed by the Python program which calculate the main PVM parameters. For convenient interaction with the software the user Tkinter-interface for the touch I/O screen is developed.

In this work testing of PVM various types was carried out in real conditions. As example on Fig.2 are shown two main stages of the measured data processing:

1. Pre-processing of the measured *I-V* samples (points in Fig. 2a) and the special piecewise polynomial approximation (blue curve on the same figure).
2. Uniform placement of points on the approximated curve (points of the blue curve in Fig. 2b), fitting the model function of the I–V characteristics (red curve)
3. Determining the PVM parameters by the microcomputer using the high-speed algorithm [3].
4. Subsequently, the obtained experimental data may be processed in accordance with the model on a PC in the MATLAB package.



a *b*

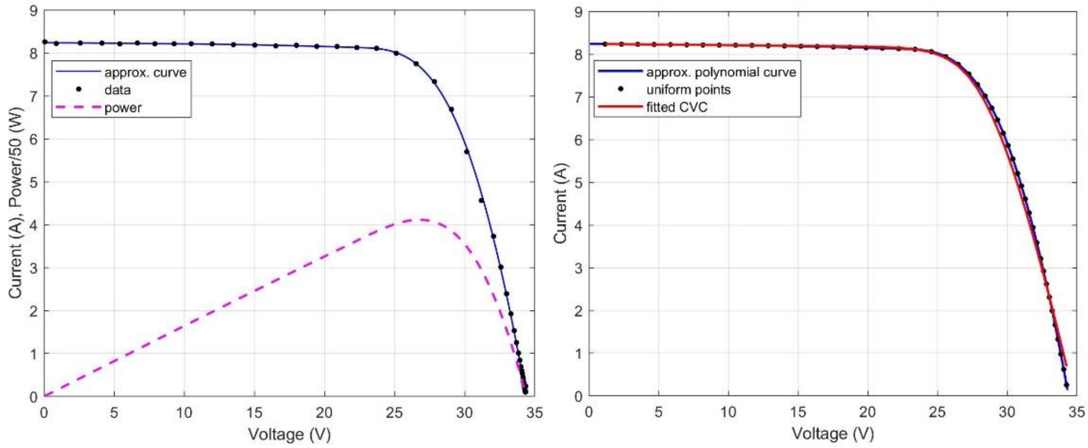
Figure 1 – Main elements of the stand-alone measuring system design: a – the control board for I-V tracking by variable resistance technology that hosts the set of relays controlled by a MOSFET, ADC and connectors for the resistance box and the PV capacitance charge control circuit; b – the compact 3D-printed case for device with sensor screen for control and results output.

The plots on figures 2 show results of processing the data for the module Risen 285 W at the irradiance 730 W/m^2. The obtained parameter values are as follows: the photocurrent I_{ph} = 8.25 A, the reverse saturation current $I_0 = 0.82 \cdot 10^{-10}$ A, the diode non-ideal factor n = 2.67, the series and parallel loss resistances R_s = 0.55 Ohm and R_p = 334.14 Ohm respectively.

An accuracy on the optimization stages we estimate by the normalized root mean square error determined as

$$NRMSE = \frac{\sqrt{\frac{1}{N}\sum_k \left(I_{\mathrm{mod},k} - I_k\right)^2}}{I_{sc}}$$

where I_k – measured points (Fig. 2a) or uniformly located points on the polynomial approximant obtained on the 1st stage (Fig. 2b) and $I_{\mathrm{mod},k}$ – corresponding values on the approximative curve of proper stage, I_{sc} – PVM short current. For 1st stage in this example it was obtained NRMSE=0.032 which characterizes above all an experimental errors. For 2nd stage NRMSE=0.018 and this value characterizes the errors of the one-diode model and the parameters extracting algorithm.



a *b*

Figure 2 – Plots of the two optimization stages (1, 2): a – measured I-V samples (black points), special piecewise polynomial approximant (blue curve) and power-voltage curve (dashed line); b – uniformly placed points on the approximant curve, fitting the model CVC (red curve).

Conclusions. The proposed method allows to quickly calculate the level of electrical losses in PV modules under operating conditions on PV plants, as well as quickly diagnose the current state of modules. Due to the special algorithm and developed measurement method, it is possible to accurately determine the main parameters responsible for ohmic and recombination losses under conditions of variable solar radiation and temperature.

References

1. P. Manganiello, M. Balato, and M. Vitelli, "A survey on mismatching and aging of PV modules: The closed loop," IEEE Transactions on Industrial Electronics, 2015, vol. 62, no. 11, pp. 7276–7286.
2. M. Cáceres, A. Firman, J. Montes-Romero et al. Low-Cost I–V Tracer for PV Modules under Real Operating Conditions / Energies Aug. 2020, 13(17), 4320, doi:10.3390/en13174320.
3. A. Gaevskii. Method for Determining Parameters of PV Modules in Field Conditions, 2019 IEEE 6th International Conference on Energy Smart Systems (ESS), Kyiv, Ukraine, Apr. 2019, p. 205-208, doi: 10.1109/ESS.2019.8764239.