MEASURING DEVICE FOR PHOTOVOLTAIC MODULES ELECTRICAL CHARACTERISTICS TESTING

Vadym Koval[1], Bogdan Orobchuk[2], Nataliia Kuzemko[3], Gao Lijin [4]

[1] *Ternopil National Ivan Puluj Technical University, Rus'ka str. 56, 46001, Ternopil, Ukraine; koval_vp@ukr.net*
[2] *Ternopil National Ivan Puluj Technical University, Rus'ka str. 56, 46001, Ternopil, Ukraine; E-mail: kuna@ukr.net*
[3] *Ternopil National Ivan Puluj Technical University, Rus'ka str. 56, 46001, Ternopil, Ukraine;*
[4]*Jinan Caigao Intelligent Technology Co., Ltd., China*

Abstract: There has been developed and produced a measuring device for measuring the electrical characteristics of photovoltaic modules. It has been experimentally tested. Its Volt-Ampere and Volt-Watt dependencies on its temperature and radiation spectrum have been collected. There have been made conclusions about device visible range spectrum radiation sensitivity and its effectiveness drop with temperature growth.

Keywords: Photovoltaic module, measuring device, radiation spectrum, temperature

1. Introduction

Problem description. Photovoltaic modules' high prices and low effectiveness are the main obstacles to their global implementation nowadays. The low effectiveness depends on many operational factors, the photovoltaic module's own temperature and the solar spectrum among them. The influence of the solar spectrum to the energy effectiveness of photovoltaic modules is especially noticeable in the morning and evening hours, as well as in cloudy weather conditions. High temperature effect is the most noticeable in the noon. That is why automated measuring devices development is important for production of new materials and protective glasses for photovoltaic devices. They are to correct photovoltaic devices' VA characteristic for their own temperature and the spectrum they are exposed to.

Recent researches of photovoltaic devices [1-4] are concentrated mainly on heating effect corrections [1,2,3], with their electrical characteristics being corrected manually. Still, sensitivity of photovoltaic modules to the different radiation spectrum has not been sufficiently studied, because the authors rely on their passports characteristics [4]. However, in this case the lighting characteristics of the protective coating or glazing are not taken into consideration.

The purpose of the present work is to design and produce more sensitive and accurate measuring device to measure electrical characteristics of photovoltaic module corrected for its temperature and the spectrum it is exposed to.

2. The description of measuring device

We have made a measuring device for automated measuring of the electrical characteristics of photovoltaic modules (Fig. 1) [5]. It is based on a personal computer with a built-in type SDI-ADC12-128H ADC board [6,7]. It digitizes data from current, voltage and temperature sensors. It features a PC-controlled variable active load, which reduces measurement time and enhances its accuracy. Lamp КГ 500 is the solar spectrum radiation and heating source for tested photovoltaic module. Light filters are used to change the radiation spectrum scope. After their replacement, the falling radiation energy is set at the level 1000 W /sqm, as required by the state standards.

A digital (typesetting) resistor is used as a controlled load. Its resistance can be varied widely with a small step according to a given digital signal. It uses high-precision non-induction resistors, which provide a purely active load without a reactive component [9]. The scheme of the variable resistor is shown on fig.2. Switching is done by a reed relay, which provides complete electrical insulation of the control (digital) part of the device.

The scheme operation is simple. It uses a set of series-connected resistors. The resistance value of each next one is twice as big as the previous one. It corresponds to the change of the binary control signal bits weight. Every resistor is shortened with a normally closed contact of a reed relay that is operated by a digital signal of a corresponding number. The initial resistance is zero. The lower digit control signal closes the contact of the first resistor. The number of bits and the lowest resistance in the set can be set according to the specific requirements. The relay is controlled by electronic keys (fig. 3). This version of the scheme can be used in combination with a binary forward/backward counter or with a microcontroller.

Current and voltage measuring converters. Current and voltage measuring converters were used to measure the time characteristics of physical values in electric circuits with photocells. The shunts of high accuracy non-inductive resistors were used as current measuring converters (their tolerance is within 0.1%). The resistors values were 0,05 ± 0,0002 Ω, 0,1 ± 0,0003 Ω,, 1 ± 0,008 Ω. Voltage drop was measured on them. These values were chosen due to the following reasons. The resistance should have the least effect on the current of the tested electrical circuit and its voltage drop should be not more than 5 V (to meet the ADC channels input voltage requirements of Vin < < ± 5 V). These shunts were calibrated at the Ternopil Research and Production Standardization, Metrology and Certification Center, which is confirmed by calibration certificates № 60 and 61. Thus, the current measuring converters rates are 1:20, 1:10 and 1:1. Since the ADC can measure voltage within -5 V … +5 V, serial dividers realized via probes to the type HP-9258 and HP-9251 oscilloscope with division rates of 1: 100 and 1:10 respectively were used.

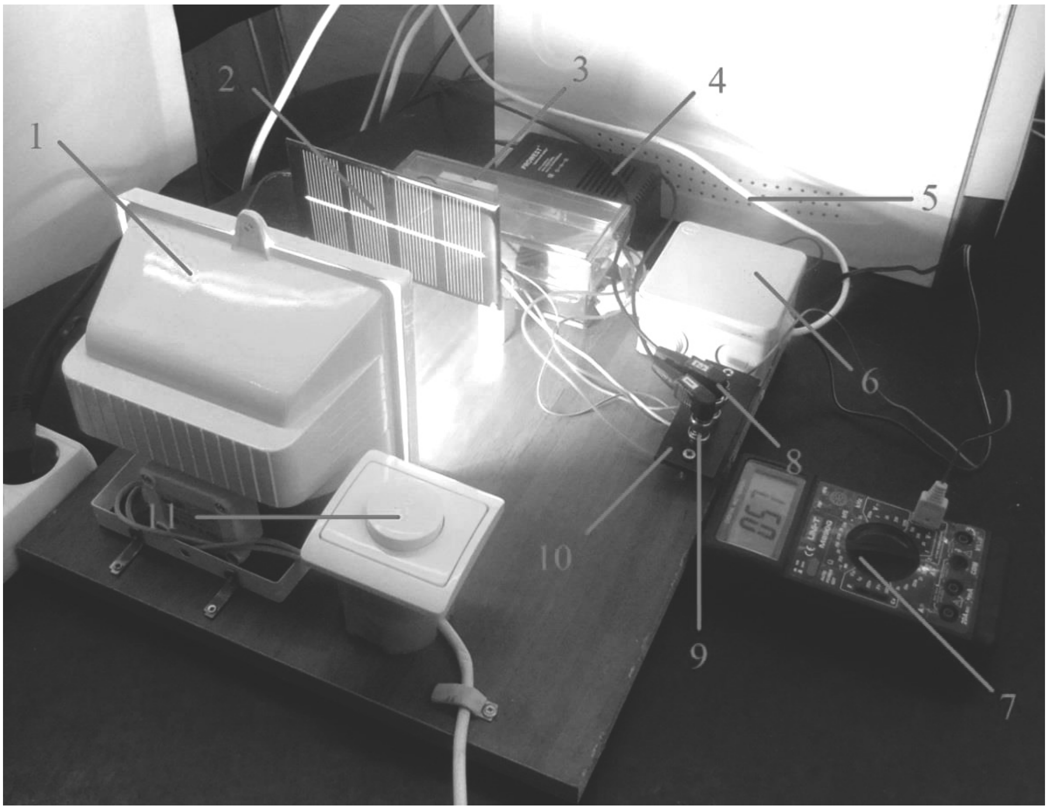

Fig.1 The device for photovoltaic modules electrical characteristics measurements

1 –lamp;
2 –photovoltaic module;
3 –variable active load unit;
4 –power supply;
5 –data bus;
6 –control unit;
7 –digital multimeter;
8 –voltage sensor output;
9 –current sensor output;
10 –temperature sensor output;
11 –light switch/dimmer

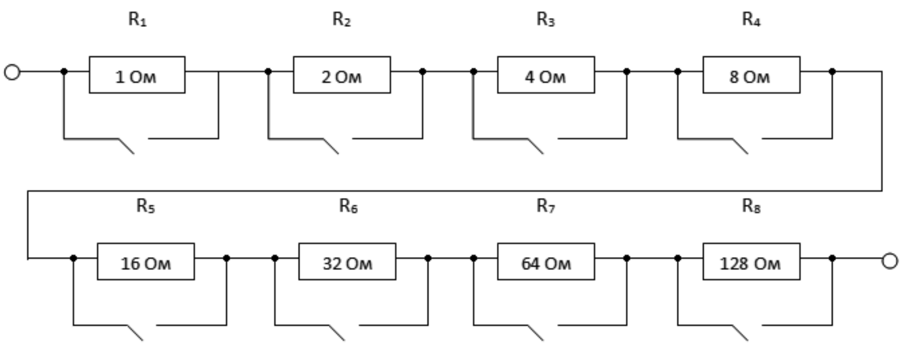

Fig.2 Variable controlled resistor

Software. The designed measuring device data were processed by the specialized and standard software. Specialized software sets the measurement algorithm, according to the method of testing, and processes the output data.

Specialized software was developed to measure and process the initial data. Microsoft Excel, MathCAD and Advanced Grapher software was used for data math processing and visual representation. The testing algorithm was realized on Delphi, because its set of commands allows addressing the PC ports directly. This fact is very important, because specialized software, in addition to the data processing, involves writing and reading data from parallel ports to which the ADC and switches are connected.

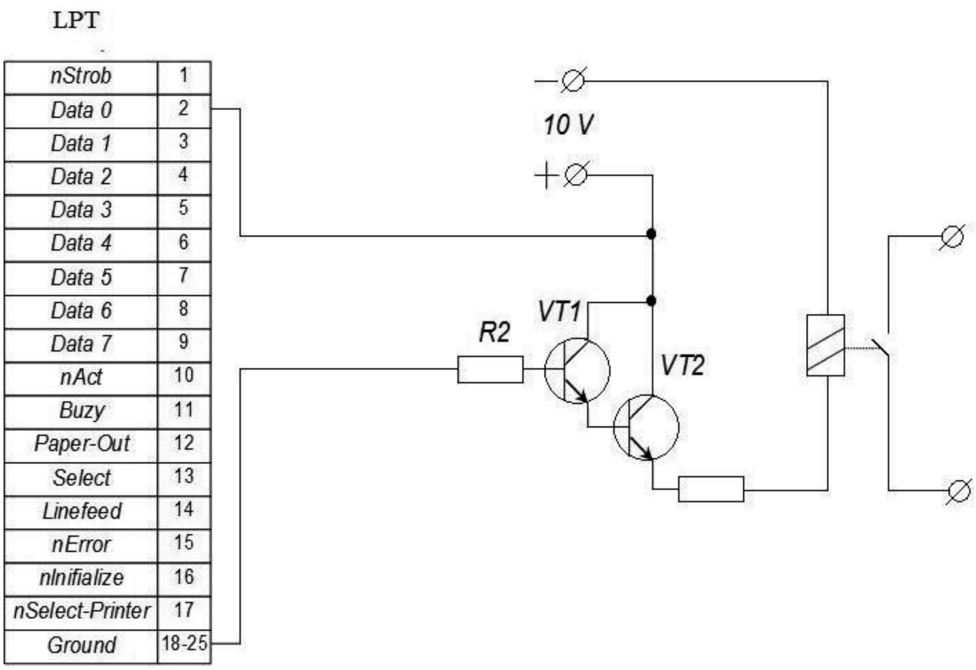

Fig. 3 Electronic switching device based on a reed switch schematic diagram

Measuring device software algorithm. The measuring device can work in two modes: manual and automatic (fig. 4). You can switch between them after power is turned on.

The temperature of the photovoltaic module (Tfm) and the max current (Imax) for the load of 0 Ω (R = 0) is measured in each mode. It is accepted by the software as a basic one, in relation to which the photovoltaic module generated current value is read out. The load resistance is increased by 1 Ω on every stage, that results in the drop of the current and the load (photovoltaic module) voltage increase that are accordingly measured at every stage. This process is carried out until the load current is less or equal to the 10% of max current (I> = 0.1 · Imax). This condition is met coming out of photovoltaic module VA characteristics. That is, the max power collected from the photovoltaic module is within Imax to 0.1 · Imax. This way, one VA dependency is collected.

In manual mode you can collect either single VA characteristic or any number of them. The latter can be done by selecting "Select next measurements?" choice box appropriate option.

In automatic mode, the photovoltaic module VA characteristics are measured as many times as necessary for the photovoltaic module transient heating to settle down. This function is performed by the operator "dTfm = <0.05 · Tfm". That means, when the temperature difference between the measurements is less or equal to 5% of the initial temperature, the measurements will stop.

The number of measurements can be adjusted by setting the time delay after the loop operator.

The measurement results are stored in the file for further processing in mathematical and tabular editors after measurement process is over.

The designed measuring device was used to test the single-crystal photovoltaic module, which is shown at fig. 1. The dependencies of the photovoltaic module generated current and power on the voltage at different temperatures (fig. 5, 6) and the radiation spectrum (fig. 7, 8) were collected. The radiation power on the surface of the photovoltaic module was controlled at the level of 1000 W / sqrm during the measurements. The radiation spectrum was changed by changing the filters. The temperature was registered by the thermocouple and monitored by the pyrometer.

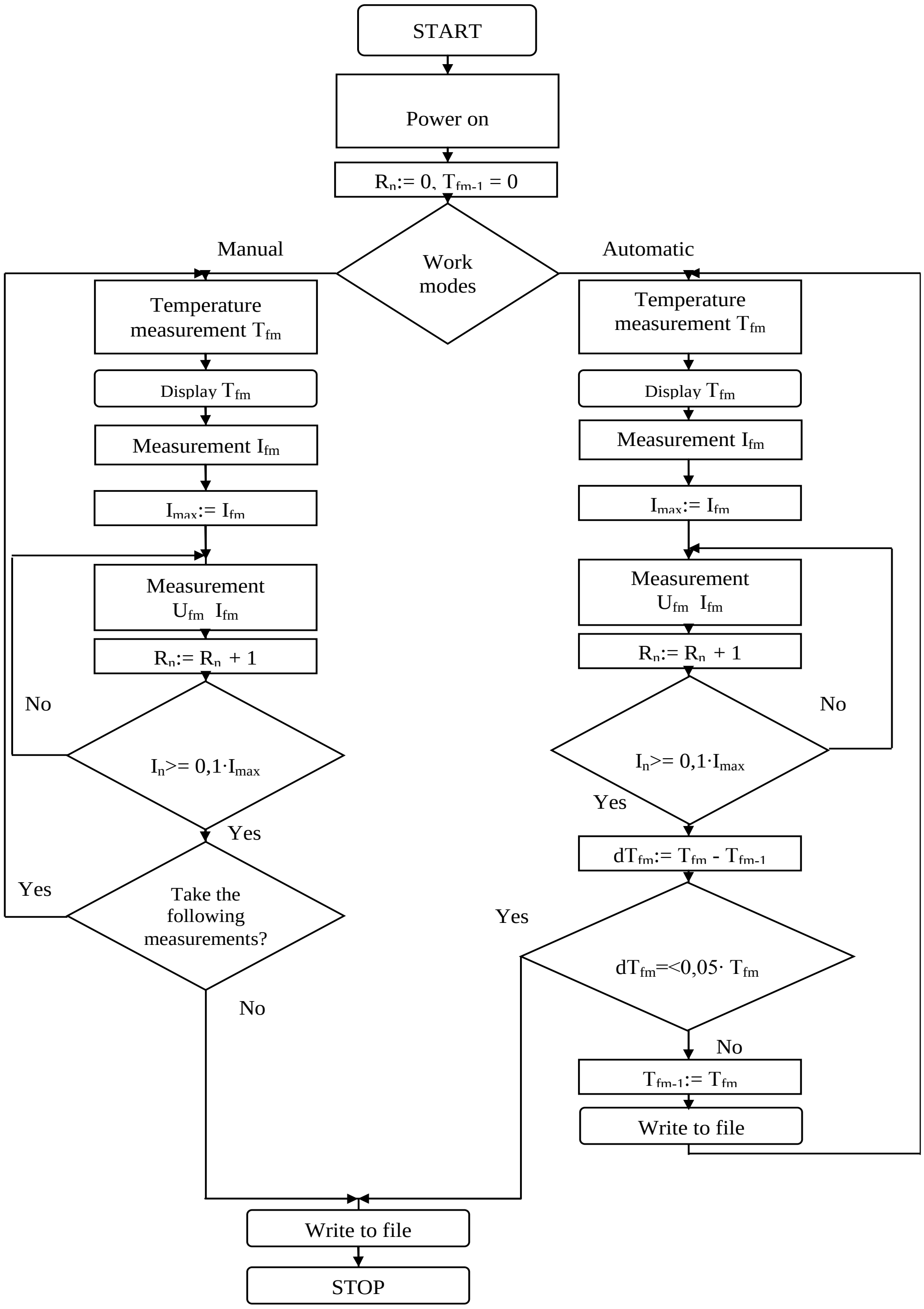

Fig. 4 Software algorithm

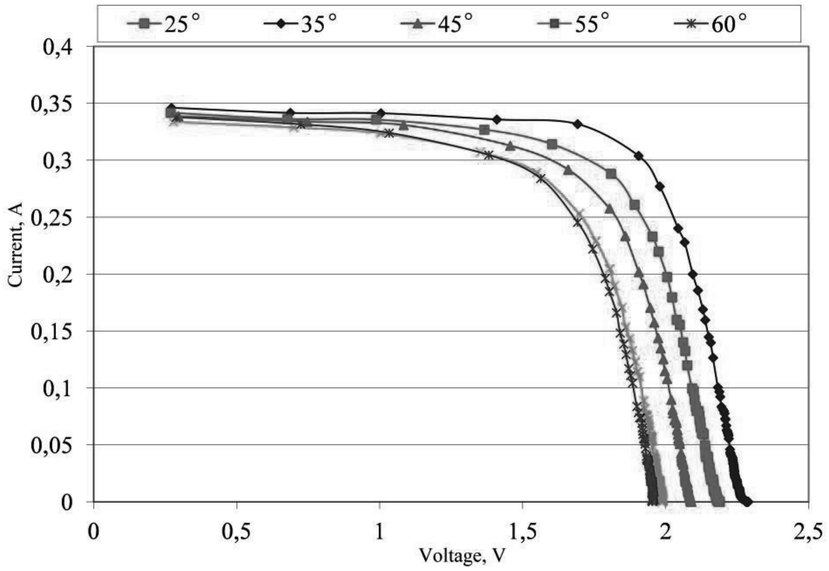

Fig. 5 The photovoltaic module generated current dependence on the voltage for different temperatures (25..60 °C)

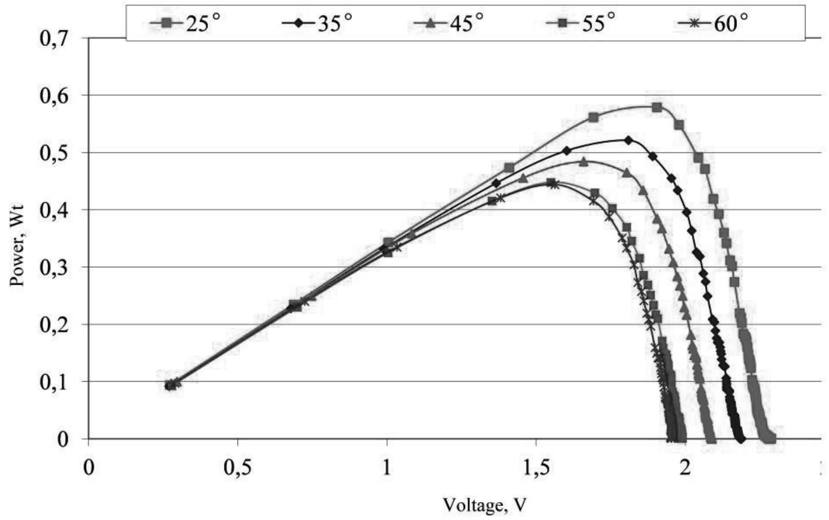

Fig. 6 The photovoltaic module generated power dependence on the voltage for different temperatures (25..60 °C)

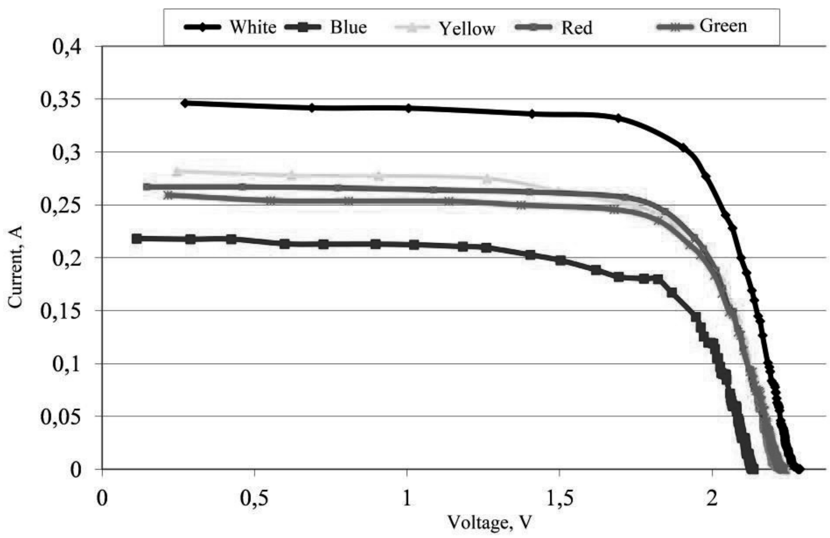

Fig. 7 The photovoltaic module generated current dependence on the voltage for different radiation spectrum

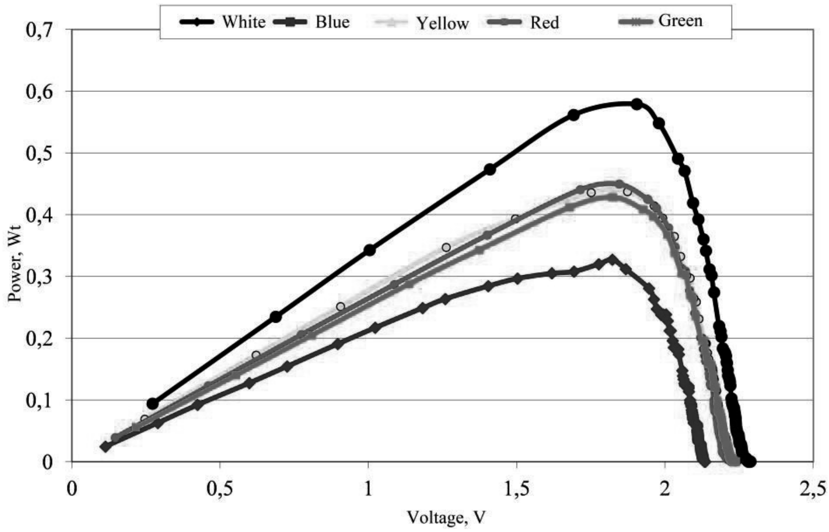

Fig. 8 The photovoltaic module generated power dependence on the voltage for different radiation spectrum

3. Conclusions

1. There has been developed and produced a measuring device for measuring the electrical characteristics of photovoltaic modules in both automatic and manual modes by use of a 16-bit ADC module personal computer.

2. Software was developed to control the operation of the measurement device and process the testing data. It allowed to automate the measurement process and has a flexible structure for the algorithm change according to the measurement techniques that allows to store and display large arrays of digital data graphically.

3. It can be stated from the obtained measurement results that when the temperature of the photovoltaic module increases from 25 to 60 ° C, the max power drops by 25%, and the green and blue lines of the spectrum are lesser absorbed than yellow and red ones.

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