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The application of labview software for the control of a model of a tracking photovoltaic system

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Summary. The paper presents the design of a test stand for tracking photovoltaic systems. For the control of the stand the authors used a universal measurement and control card LabJack U12 and the control algorithms were realized in the LabVIEW environment. The test stand was adapted for testing of different types of cells and different types of control.

Key words: photovoltaic conversion, tracking system, photovoltaic cell, and photovoltaic panel.

INTRODUCTION

The tests on tracking photovoltaic systems are usually conducted on prototype or low series load bearing structures [12, 13, 6, 15]. An even greater variety is encountered in the control mechanisms in the case of both the actuators and the control algorithms. In general, we can distinguish two types of control algorithms in the tracking photovoltaic systems: systems that track the maximum solar radiation in set time intervals and systems that set the receiver plane perpendicularly to the direct radiation according to the astronomical algorithms [11, 9, 21].

In all the cases there are many important aspects that require in-depth fundamental research. The results of the tests on the test stand can be the rationalization of the selection of the design and functional parameters of the tracking photovoltaic systems.

AIM OF THE WORK

The aim of the task is to construct a test stand that will enable the performance of a variety of fundamental research of the tracking photovoltaic systems. The element supervising the functioning of the control system is a universal measurement card LabJack U12 supported by LabVIEW that enables programming of the algorithms in G graphic language [1].

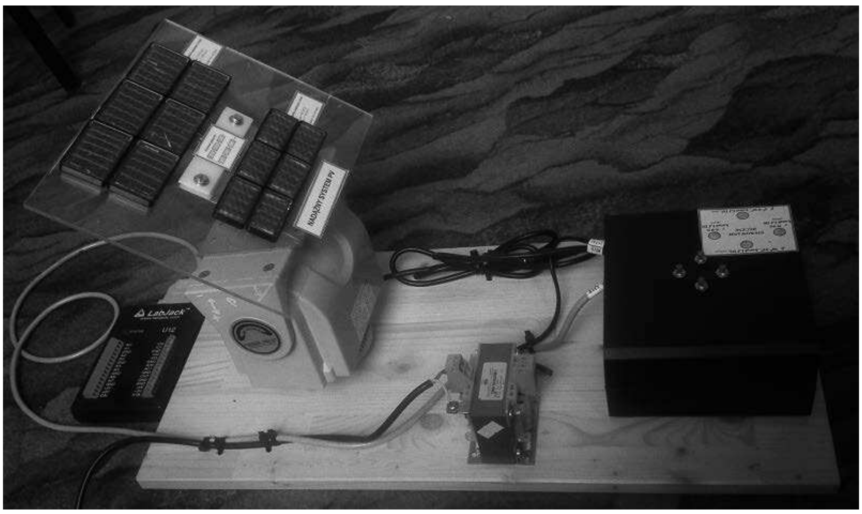

Fig. 1. Image of the test stand

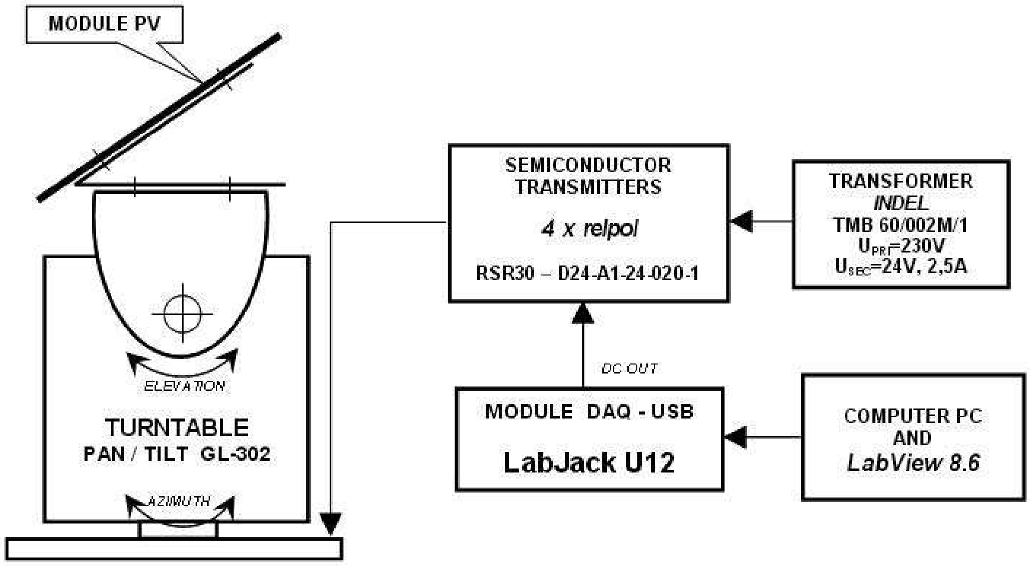

Fig. 2. Schematics of the test stand

DESCRIPTION OF THE TEST STAND

For the needs of the research of the tracking photovoltaic systems a stand was built as seen in Fig. 1. The actuator is an adapted PAN / TILT camera GL-302 tracker motor on which the photovoltaic panel was fixed.

Detailed schematics of the connections of the test stand has been presented in Fig. 2. The control is realized through a universal control and measurement card LabJack U12 supported by a PC computer connected via a USB port. The power supply of the control system is realized through a 24 V adapter and semi-conductor relays RELPOL RSR30. The stand also enables manual operation of the tracker motor. The control algorithms are built in the G graphic language in the LabVIEW 8.6 environment.

The tracker motor operates in two planes: azimuth (rotation angle - γ) and elevation (angle of incidence - β). Owing to the use of a special support and end switches of the tracker motor the following ranges of rotation have been obtained: for the angle of rotation in the azimuth plane (γ): 45^0-315^0 (measured from the north direction clockwise) and for the angle of incidence (β): 0^0-90^0. For the used power supply and control systems the rates of rotation of the model of a tracking photovoltaic system were determined experimentally in both planes: azimuth plane (for angle γ) – 4.41 [^{0}/s] and elevation plane (for angle β) – 4.95 [^{0}/s]. On the test stand two sets composed of six serial photovoltaic cells are fitted. The cells are made from polycrystallic silicon of the parameters: 450 mV and 100 and 200 mA respectively.

METHODOLOGY OF RESEARCH

Fig. 3 presents the schematics of the geometrical codependence in the system between the direct radiation and the plane of the radiation receiver.

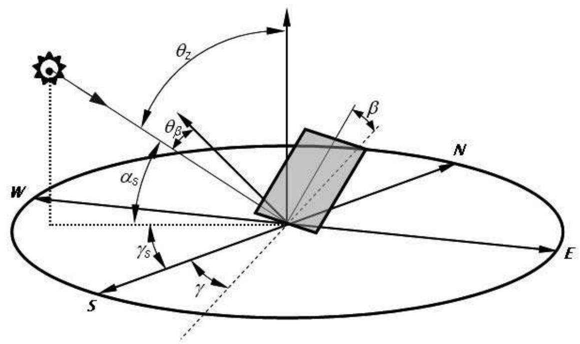

Fig. 3. Geometry of the solar radiation system–plane of the radiation receiver, where: β – angle of incidence of the receiver against horizon; γ – receiver azimuth– deviation from the local parallel of longitude measured against south (to the east it is negative, to the west– positive); γ_S – the Sun azimuth– deviation of the direct solar radiation from the south; θ_β – angle of radiation on the plane of the receiver measured between the direct solar radiation and the regular for the receiver; θ_Z – angle of zenith being at the same time the angle of solar radiation on the horizontal plane; α_S – the Sun elevation – the angle of the direction of the radiation to the plane of the horizon

The aim of the control systems of the tracking photovoltaic systems is to set the plane of the receiver so that the direct component of the solar radiation falls on the plane perpendicularly [2, 3, 4, 20]. Converting this aim into a mathematical notation we can show it as follows:

$$\gamma = \gamma_s, \quad (1)$$

$$\beta = \theta_z \quad \text{that is} \quad \beta = 90^0 - \alpha_s. \quad (2)$$

Another approach in seeking of the optimum position of the plane of the radiation receiver is determining of the Sun position through radiation sensors. A detailed analysis of the functioning of the control systems allows establishing the time interval between the settings of the individual positions. The idea behind such an approach to the control of the tracking photovoltaic systems is a compromise between the energy benefit resulting from the application of the control system and the energy consumption used for this very control. Such an analysis, apart from the solar radiation and temperature should also take into account the direction and strength of the wind while using the trackers in the location where the system is fitted [7, 10, 17, 14].

The mapping of the Sun trajectory in the sky during the day can be presented graphically in the coordinates $\alpha_S=f(\gamma_S)$. It is a graph of the Sun position that is a set of lines for individual days of the months and the latitude. Detailed mathematical relations and graphs of the Sun position for the characteristic locations in Poland can be found in literature e.g. [5, 16, 6]. Fig. 4 presents a diagram made in LabVIEW that realized the algorithm of the setting of the fitting plane of the photovoltaic cells in line with the direct solar radiation.

The icon marked ‘ALGORITHM’ in the diagram contains a set of mathematical relations described in detail in literature [16, 21] that were placed in a special block of the G graphic programming language referred to as ‘Formula Node’. As seen in Fig. 4 the input parameters in the proposed algorithm is time and location and the output quantities - the angle of incidence of the receiver (β) and the solar azimuth (γ_S). The output values of these angles are then converted into times of rotation of the trackers in the elevation and azimuth planes. Another stage of the algorithm is the use of two ‘flat sequences’ of the G graphic language. In both flat sequences to control the digital outputs of the LabJack U12 measurement card special functions ‘LJ EDO’ were used provided by the card manufacturer that make the LabVIEW software compatible with LabJack U12. The effect of the operation of the algorithm is the actuation of the tracker motors for a preset time, which realizes the displacement of the photovoltaic cell.

The influence of the application of the control of the tracking photovoltaic systems will be presented in the form of example current/voltage (I-V), characteristics performed according to the methodology described in detail in the author’s college handbook [Sarniak 2008].

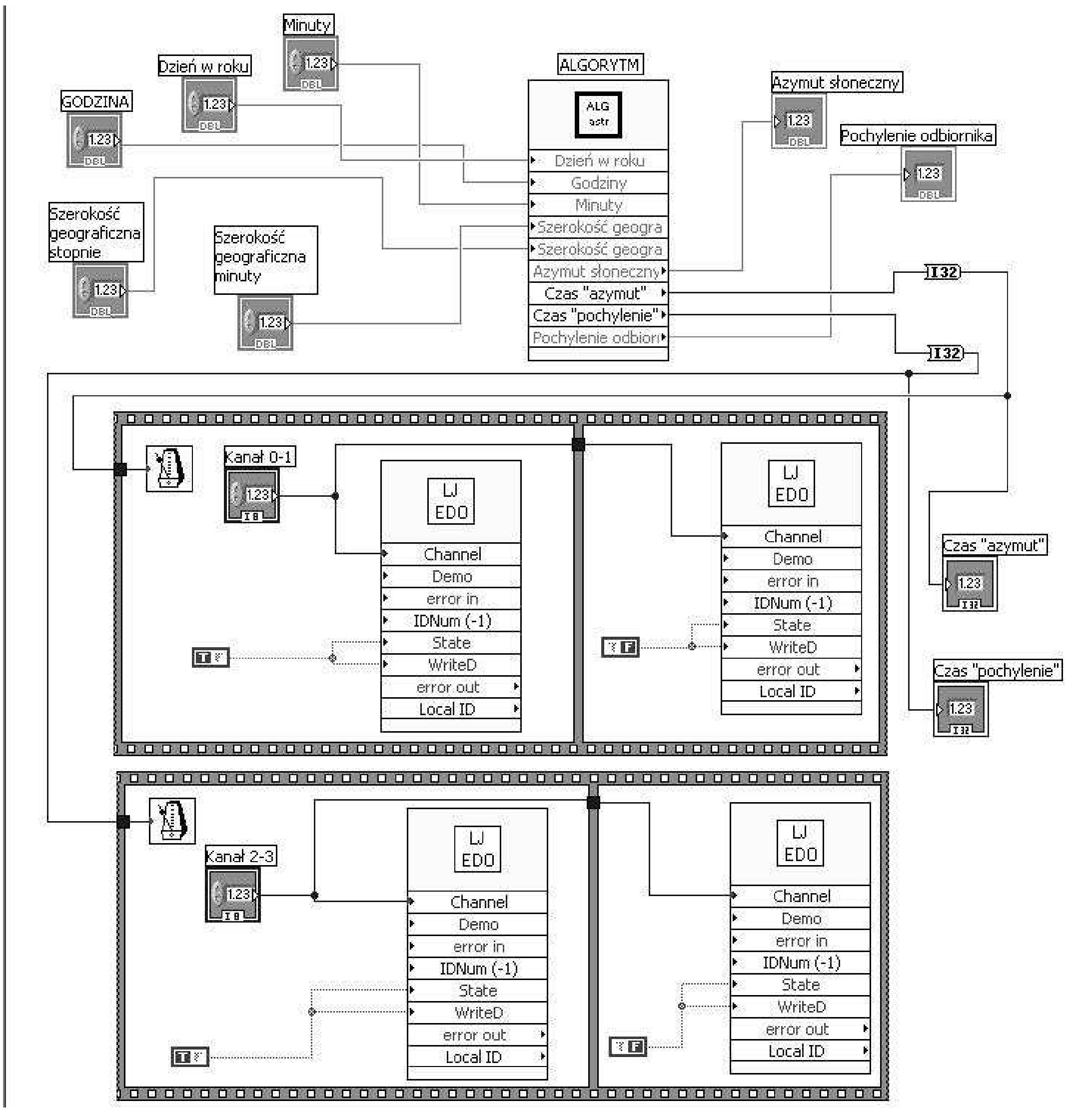

Fig. 4. Diagram presenting the control algorithm of a tracking photovoltaic system model built in LabVIEW 8.6

RESEARCH RESULTS

As a result of the operation of the algorithm the theoretical optimum positions of the plane of the photovoltaic module were determined for the example tests, as shown in table 1.

Table 1. Theoretical optimum positions of the photovoltaic module for the test location of the model test stand

Hours of measurements performed on 16.03.2012r.	Results of the calculations for the location: $52^0$28'N $19^0$40'E	
	γ_S [^{0}]	β [^{0}]
9^{00}	131.69	64.63
12^{00}	183.14	53.99
15^{00}	233.27	66.95

For these three positions the current/voltage (I-V) characteristics were measured and compared with their courses for the stationary photovoltaic system. In literature [e.g. Pluta 2000] it is recommended that the stationary photovoltaic systems be fitted azimuthally directed south and the angle of incidence be set on the level equaling the earth's latitude.

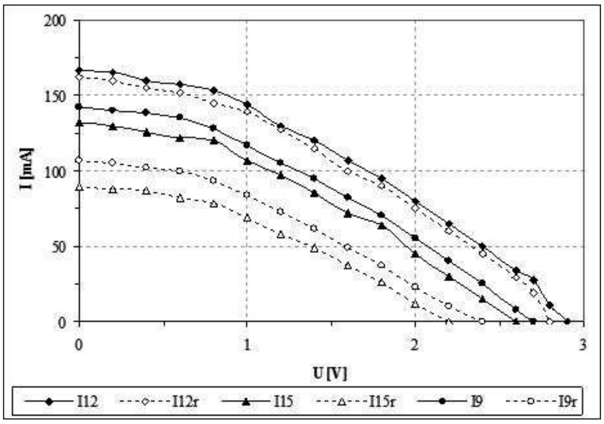

Fig. 5. Current /voltage (I-V) characteristics performed on 16.03.2012 at 9^{00}, 12^{00} and 15^{00}

Fig. 5 presents the I-V characteristics for three hours (9^{00}, 12^{00}, 15^{00}) of the day (16.03.2012). These characteristics were performed for the location given in table 1. The solid lines denote the I-V characteristics for the optimum settings resulting from the calculation algorithm and the dotted lines the I-V characteristics for the stationary all-year setting. The all-year position of the tested panel was set using the manual control on the model test stand. The preliminary tests on the model test stand were conducted at full sun operation i.e. direct sun radiation dominating. The I-V characteristics shown in Fig. 5 were developed for the cells of the following electrical parameters: 450 mV and 200 mA.

CONCLUSIONS

1. The I-V characteristics made for 12^{00} hrs only slightly deviates from the one that was made for the all-year position. This is a result of the fact that angular values of the photovoltaic cell position calculated from the algorithm are very close to the all-year ones.

2. Significant differences can be observed for the measurements for 9^{00} and 15^{00}. They can be estimated here at the level of 45-50 [mW] of the maximum power. In this case the purposefulness of tracking photovoltaic systems is confirmed.

3. Better electrical parameters of the I-V characteristics for 9^{00} in relation to 15^{00}, despite apparent time symmetry to the noon, probably result from the negative temperature coefficient for pollycrystallic silicon used in the model of the photovoltaic system,.

4. The preliminary investigations presented in this paper substantiate the need for further, more detailed research of this issue in terms of the possibilities of a more efficient use of the photovoltaic systems.

5. The investigations into tracking photovoltaic systems can be very wide in range. Tins range includes a variety of types of the photovoltaic modules in a variety of solar radiation conditions. The economic aspect is also important showing in which cases it is economically beneficial.

6. The effect of further research on the model test stand will be the determination of the optimum control algorithm for the tracking photovoltaic system and final programming of the single-circuit microprocessor such as ATMega644p in the BASCOM language for the control of the autonomous system.

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ZASTOSOWANIE OPROGRAMOWANIA LABVIEW DO STEROWANIA MODELEM NADĄŻNEGO SYSTEMU FOTOWOLTAICZNEGO

S t r e s z c z e n i e. W pracy przedstawiono projekt stanowiska do badań nadążnych systemów fotowoltaicznych. Do sterowania stanowiskiem wykorzystano uniwersalną kartę pomiarowo-sterującą LabJack U12, a algorytmy sterowania są realizowane w systemie LabVIEW. Stanowisko jest przystosowane do badania różnych typów ogniw i różnych algorytmów sterowania.

S ł o w a k l u c z o w e: konwersja fotowoltaiczna, system nadążny, ogniwo fotowoltaiczne, panel fotowoltaicznym.