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## Design and Implementation of a Solar-Tracking Algorithm

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### Abstract

The paper presents a solar-tracking method for control of photovoltaic panel movement in order to improve the conversion efficiency of the system. The designed algorithm is implemented on a solar-tracking experimental platform using a tri-positional control strategy. It makes use of measured values for radiation from appropriate sensors and assures command of the platform's two positioning motors. The solution was developed as a virtual instrument, using the graphical programming environment, LabVIEW. This allows for fast deployment, versatility and scalability.

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### 1. Introduction

The increasing energy demand, continuous drawback of the existing sources of fossil fuels and increasing concern about environmental pollution pushed researchers to explore new technologies for the production of electricity from clean sources, renewable such as solar, wind etc. Solar energy is the oldest primary source of energy. It is a source of clean, renewable energy and it is found in abundance in every part of the world. Using solar energy is possible to convert it into mechanical energy or electricity with adequate efficiency.

Information about the quality and amount of solar energy available at a specific location is of prime importance for the development of a solar energy system. However, the amount of electricity that is obtained is directly proportional to the intensity of sunlight falling on the photovoltaic panel.

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To get a larger amount of solar energy the efficiency of photovoltaic systems have been studied by a large number of scientists and engineers. In general, there are three ways to increase the efficiency of photovoltaic systems. The first method is to increase the efficiency of power generation of the solar cells, the second is related to the efficiency of the control algorithms for the energy conversion, and the third approach is to adopt a tracking system to achieve maximum solar energy.

The interesting in the photovoltaic tracking systems as a new method for studying and teaching increased in the passed years. A wide number of papers, such as [8] and [9], describe a consistent number of photovoltaic panel solar tracker applications and their area of employment. Paper [5] shows the potential system benefits of simple tracking solar system design using a stepper motor and light sensor. In [10] a single-axis sun-tracking system with two sensors was designed. The data acquisition, control and monitor of the mechanical movement of the photovoltaic module were implemented based on a programmable logic-controlling unit. The authors of [1] presents the design and construction of a two axis solar-tracking system in order to track the photovoltaic solar panel according to the direction of beam propagation of solar radiation. To achieve maximum solar energy, solar power systems generally are equipped with functions which are calculating the maximum power point tracking (MPPT) as shown in [11, 12 and 13]. Our work enhances previous related developments through design and modeling of tri-positional command structures.

This paper presents the design and implementation of a two axis solar-tracking algorithm in order to improve the availability of solar energy and to improve the system's total efficiency. The presented system and algorithm have the following advantages: the photovoltaic panel physical model is a didactic system and the programming environment in which it is developed the presented algorithm allows designers faster and easier development of block diagrams for any type of data acquisition, analysis, and control application. This implementation technique reduces the costs of tracking method and makes it a cost-effective technology.

The rest of the paper is structured as follows. Section 2 describes in detail the hardware structure of the solar-tracking experimental platform and its characteristics. Section 3 is dedicated to the theoretical design of the tri-positional control algorithm and its implementation as a virtual instrumentation system. Section 4 presents the experimental results obtained by using the proposed algorithm. Section 5 concludes the paper and draws the main directions for future work.

## 2. Equipment description

In order to implement tracking algorithms, solar panels have to be placed on a structure that allows moving (rotating) of the panel on one or preferably two axis. In addition, the structure with one or two degrees of freedom must dispose of actuators for effective movement.

The equipment used in the experiments is a didactic miniature equipment, which is equipped with a set of three photovoltaic cells that are placed on the same plane, in the upper bar assembly. The frame on which are mounted the solar cells includes two motor-powered from direct current (DC) supplied at a constant 24 voltage and which allows the positioning on two axes of rotation. The allowed movements of the solar panels on the mechanical structure are the horizontal direction (azimuth angle) and the angle of inclination (elevation angle). It appears that the azimuth angle variation is wider compared to the time of day and the elevation variation is relative to the time of year (season). This behavior is due to the trajectory of the sun throughout the day, depending on the season.

Figure 1 shows schematically the basic structure of the equipment described above.

In addition, in order to determine the maximum light intensity on the underlying photovoltaic cells panel four photosensitive cells can be found (two on each direction, on the neighboring sides of the panel and perpendicular to it - see Figure 2).

The operating principle of the photosensitive cells is the following: the increasing light intensity generates tension augmentation across photosensitive cells. All terminals are available for measurements and for integration into the developed control loop.

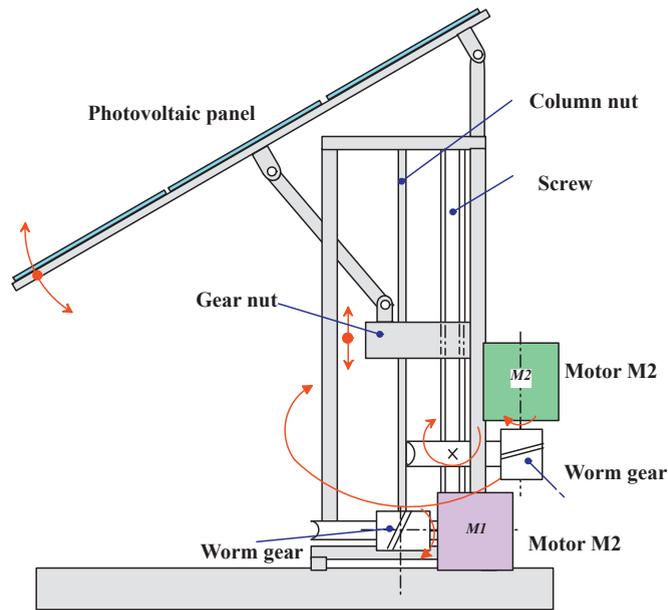


Fig. 1. The mechanical structure for the positioning of the solar panels.

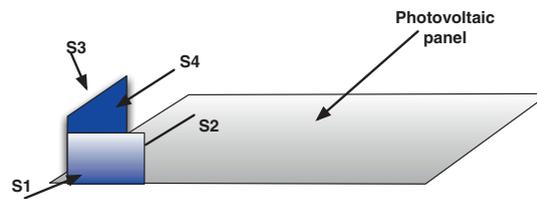


Fig. 2. The sensitive elements mounted perpendicular to the panel surface.

### 3. The command structure

To position the photovoltaic panels, given the available structure as it was described previously, a control algorithm was implemented in order to obtain an efficient positioning of the mechanism. In the following sections, the control algorithm and its implementation are described.

#### 3.1. The command algorithm

Taking into account the manner in which the two motors (discrete states - on/off) can be controlled, it was concluded that an efficient method for the command is the implementation of control loops with tri-positional controllers.

The exit signal of the process, are four pairs of signals (four sensors i.e. the photosensitive cells), which can determine the maximum luminous intensity and two continuous current motors have to be controlled in order to obtain the desired position of the photovoltaic panels. The process has four inputs and two outputs which can be unlinked, resulting in two independent control loops. Figure 3 presents the control loop for one of the control loops (either for the azimuth or for the elevation).

From figure 3 the subsequent blocks, inputs and outputs for one loop can be identified as followed:

- A motor from whom it can be controlled the two directions of movement
- A tri-positional controller, RA, which commands the directions of movement of the motor depending on the sign and magnitude of the error
- $y_1$  and  $y_2$ , represent the signals from the sensitive elements S1 and S2
- $y_r$ , defines the reference and represents the proper system positioning
- $\varepsilon = y_r - y$ , is the error, i.e. the difference between the command signal generated by the controller in order to move the motor in one direction or in other, depending on the sign of the error  $\varepsilon$  and the reference.

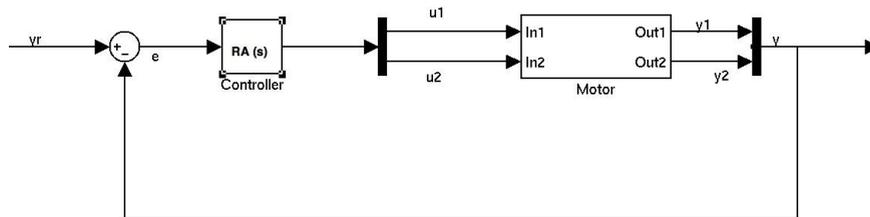


Fig. 3. The control loop of the motors.

The following notations are considered:

Nomenclature	
$y_1$ and $y_2$	represents the signals from the sensitive elements S1 and S2
$y_r$	defines the reference and represents the proper system positioning
$y =  y_1 - y_2 $	
$\varepsilon = y_r - y$	is the error, i.e. the difference between the command signal generated by the controller in order to move the motor in one direction or in other, depending on the sign of the error $\varepsilon$ and the reference.
RA	the transfer function of the controller

By reporting the parameter  $\varepsilon$  to the  $[-y_r, y_r]$  range, the function for the tri-positional controller can be induced as followed:

$$u_1 = \begin{cases} 1 & \text{if } \varepsilon < -y_r \\ 0 & \text{if } \varepsilon > -y_r \end{cases} \quad (1)$$

$$u_2 = \begin{cases} 1 & \text{if } \varepsilon > y_r \\ 0 & \text{if } \varepsilon < y_r \end{cases} \quad (2)$$

### 3.2. The algorithm implementation

The implementation of the control algorithm is numerically through a specialized device and computing program capable to acquire analog and digital input, to make a series of preliminary data processing, to take a set of decisions about the way the process should be influenced and to update the output signals according with the set the decisions taken. Because now it is easier to interface with real-world signals, analyze data for meaningful information, and share results the LabVIEW environment was chosen for the implementation of the control algorithm [2, 3].

LabVIEW is a graphical control, test and measurement environment development package. The programs created in LabVIEW have three basic components: the front panel, the block diagram, and the icon connector. The control panel is the user interface and the code is inside the block diagram that contains the graphical code [4, 7].

In the front panel, one can add the number of inputs and outputs that the system requires. Controls and indicators can classify the basic elements inside the front panel. The general type of numerical data can be integers, floating,

and complex numbers. Another type of data is the Boolean, useful in conditional systems (true or false), as well as strings, which are a sequence of ASCII characters that give a platform-independent format for information and data [6]. Using control loops, it is possible to repeat a sequence of programs or to enter the program conditions.

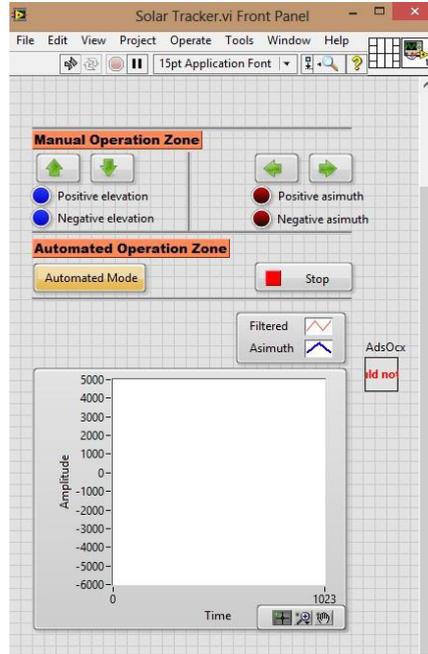


Fig. 4. The designed algorithm – LabVIEW control panel.

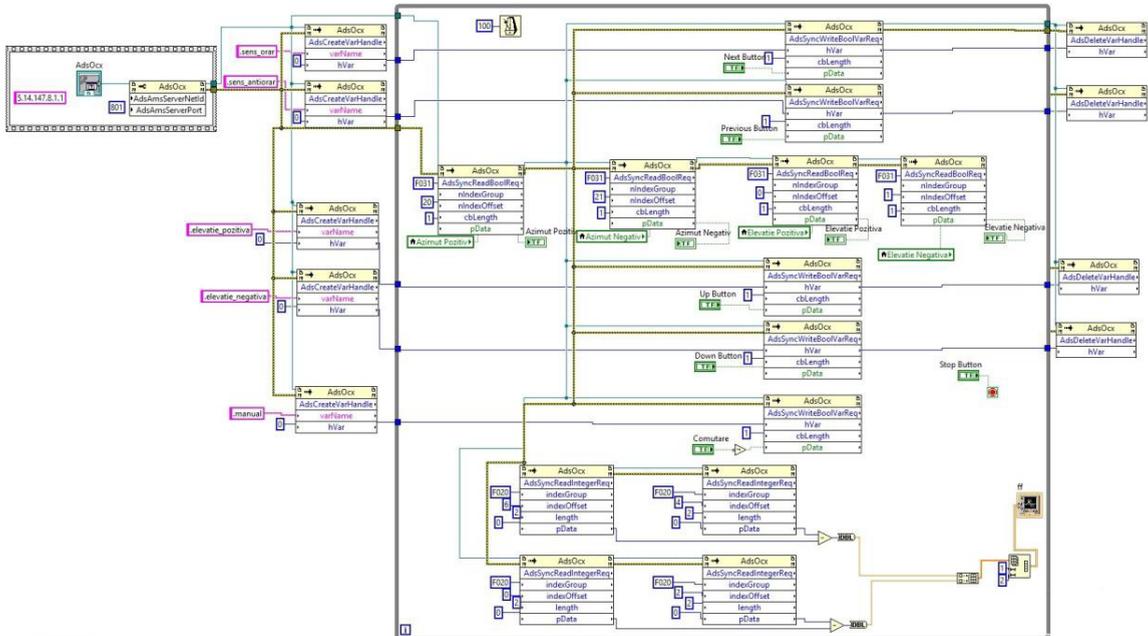


Fig. 5. The designed algorithm – LabVIEW front panel.

### 4. Experimental results

The communication between the solar-tracking system and the informatics system (PC) was realized with the help of a National Instruments acquisition board (NI BUS 6008 – Figure 6). In addition to this acquisition board it was required building an intermediate board, which makes possible the communication between the NI acquisition board and solar-tracking system (Figure 7). The front view and the electronic view of the two acquisition boards are presented in this section.

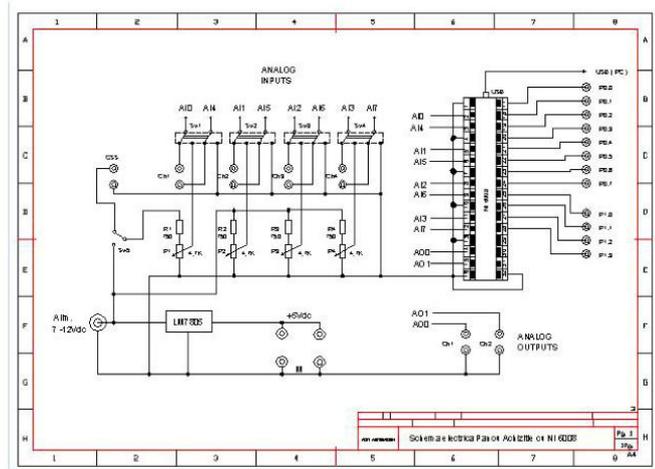
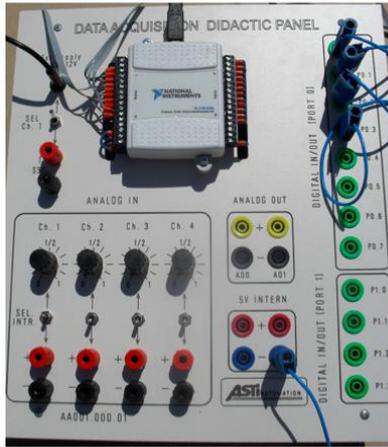


Fig. 6. (a) NI BUS 6008 front view; (b) NI BUS 6008 electrical view.

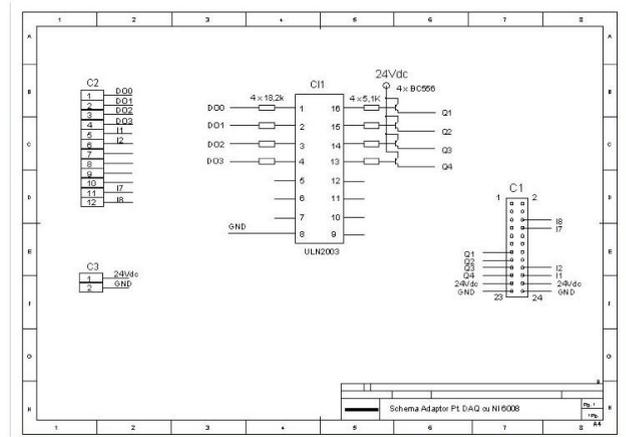
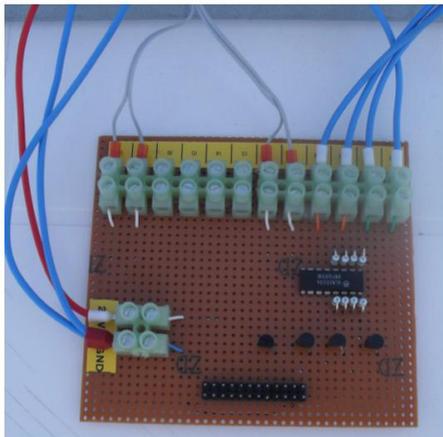


Fig. 7. (a) Front view of the connection board between the solar-tracking system and the NI BUS 6008; (b) Electrical view of the connection board between the solar-tracking system and the NI BUS 6008.

Using the control algorithm which was described above, the results obtained for the controlling of one motor are synthesized in figure 8.

Figure 8 illustrates the output of the motor 1, i.e. the elevation motion of the system.

With the help of the proposed algorithm the efficiency of the solar panel was increased. It was shown that the use of this technique can capture large amount of solar energy. For this reason the use of the non conventional energy will increase which is a very fruitful incident for the future power sector.

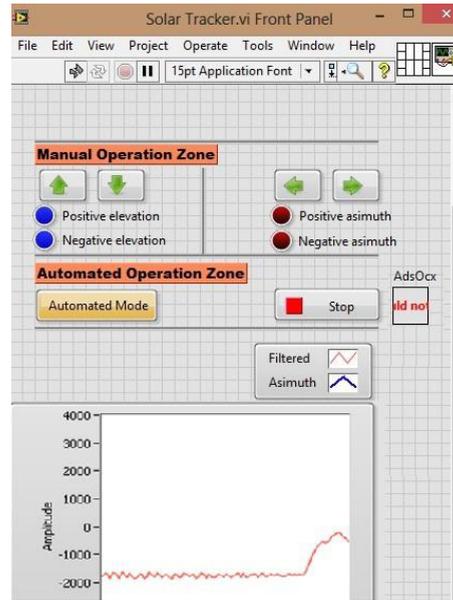


Fig. 8. The designed algorithm – LabVIEW results.

## 5. Conclusion

This paper presents a solar-tracking method design and implementation for experimental sun follower platforms. The presented control algorithm commands the movement of a photovoltaic module in order to follow the sun's radiation and to maximize the obtained solar energy. The programming environment (LabVIEW) in which the presented algorithm is developed allows designers faster and easier development of block diagrams for any type of data acquisition, analysis, and control application. This implementation technique reduces the costs of tracking method and makes it a cost-effective technology.

Regarding future work, this will follow two main directions. First, extensive experimental evaluation has to be carried out in order to validate our approach. Second, a comparison between different control strategies in similar operating scenarios will lead to choosing the best solution depending on the situation.

## Acknowledgements

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