RESEARCH ON THE DEVELOPMENT OF AZIMUTHAL TRACKING SYSTEMS USED FOR PHOTOVOLTAIC PANELS ORIENTATION

Lecturer Eng. **Constantin UNGUREANU**, PhD[1]
Eng. **Condruț-Ștefan ABABII**[2]

[1]„Stefan cel Mare" University of Suceava, Electrotechnics Department, Suceava, Romania
[2]EGGER Rădăuți, România

REZUMAT. Lucrarea prezintă cercetări în legătură cu optimizarea sistemelor de orientare biaxiale. Identificarea poziției Soarelui se face cu ajutorul unui sistem de control pe bază de date meteorologice statistice privind poziția zilnică a Soarelui, cu posibilitatea de a selecta diferite zone geografice. Este prezentată schema bloc a sistemului de orientare şi interfața grafică de control a orientării prin intermediul motoarelor de acționare.

Cuvinte cheie: sistem activ de orientare biaxial, azimut, altitudine.

ABSTRACT. This paper present researches about optimization of the biaxial tracking systems. Sun position identification is done using a control system based on statistical weather data, concerning daily position of the Sun with the possibility to select different geographic areas. The block diagram of the tracking system and graphical interface for orientation control, through the actuators, is presented.

Keywords: biaxial tracking system, azimuth, altitude.

1. INTRODUCTION

One of the disadvantages of solar energy is that the Sun runs a diurnal apparent motion in the sky, which is why some solar converters (heliostats, solar panels, etc.) require continuous tracking. In addition, this movement is not the same every day, because of revolution of the Earth around the Sun.

For this reason, even with the use of flat collectors (without concentrator), which usually have a fixed position, it is necessary to know the movements to determine optimal position of the collector inclination versus horizontal ground.

Due to the apparent diurnal motion of the Sun in the sky, sunlight falling on the Earth at an angle which varies from one place to another, from one hour to another, from one day to another, from one season to another. Specifying the relative position of the Sun to some coordinate systems attached to Earth is indispensable in the design and study of solar energy installations.

This paper presents a study of the active tracking systems that use for the orientation on the azimuth and altitude of a photovoltaic panel, stepper motors.

Photovoltaic panel orientation in the azimuthal system is based on statistical weather data regarding the daily position of the sun for different geographical areas.

Tracking systems for photovoltaic modules use controlled orientation mechanisms that minimize the incidence angle (the angle between the solar beam and the normal to the PV panel) in order to maximize the perceived power of the PV panel while minimizing energy consumption for tracking.

Orientation mechanisms whose joints make angular displacements on both axis, constitutes azimuth mechanisms class. The main feature of a tracking system is to increase the received radiation to the surface of PV module.

Efficiency of photovoltaic modules is significantly improved if they always follow the sun's path, so that the angle of incidence of sunlight and normal modules is minimal or zero.

To achieve this requirement is required modelling of sunlight angles relative to the Earth which must be precise, simple, without requiring the calculation difficulties and easy to interpret.

In the study of energy efficiency and tracking system design should consider the following climatic parameters: direct and diffuse solar radiation, wind speed and direction, turbidity factor, temperature and humidity.

Climatic parameter which influence the energy efficiency of solar energy conversion systems is solar radiation. Therefore, for optimal design of tracking systems for a given geographical area, it is necessary the acquisition and processing of local climatic parameters [5].

After method identification of the Sun's position (the point with the highest brightness) in the sky, command / control systems can be classified into [4]:

- Photo-sensor systems, able to detect the position of the Sun in the sky;
- Operating systems based on statistical weather data on daily position of the sun in a year.

In terms of the number of tracking systems that control device can manage, are distinguished [4]:

- Individual control system at which every tracking system is controlled by its own control system that autonomously manages optimal movements to be performed according to the actual operating conditions;
- With the central control system - CCU, which can handle up to 100 parks with tracking systems [8].

2. ANGULAR POSITION OF THE SUNLIGHT

Systematization and analysis of orientation mechanisms used to guide photovoltaic modules, can conclude that a tracking system is technically efficient and economically only if the following three conditions are fulfilled simultaneously [1, 7]:

□ require a low consumption of material resources;
□ can maximize the perceived incident radiation on the photovoltaic module;
□ energetic consumption is small enough for orientation.

All variants of modeling characterizes the angular position of the sun, in the equatorial system, based on two angles: declination angle δ and ω hour angle.

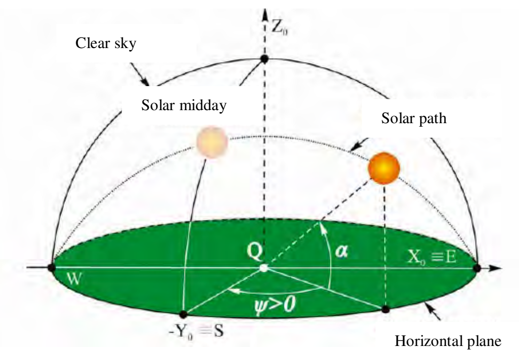

Fig. 1 Azimuthal angle system (reproduced from [3, 4]).

Declination δ is the angle between the center axis of the Earth - Sun and Earth's equatorial plane and the angle ω is the dihedral angle formed by meridian plane the observer's land and meridian plane of sunlight [3, 4].

The azimuthal system (Fig. 1) consists of the horizontal plane of the site (the observer) on Earth and vertical location. In relation to this system, the relative position of the sun is described by angles: azimuth and altitude.

Altitude angle (α) is the angle between the horizontal plane and the solar ray. Specialized literature proposes to calculate the angle, relationship [3, 4]:

$$\alpha = \sin^{-1} (\sin\delta \sin\varphi + \cos\delta \cos\varphi \cos\omega),$$

where φ is the latitude of the site, δ is declination angle, ω is the hour angle.

Azimuth angle (ψ) is the angle in the horizontal plane of the site, formed by the solar ray projection and by a line directed from N to S.

Following equation is proposed for calculating the azimuth angle [3, 4]:

$$\Psi = (\text{sgn}\ \omega) \arccos [(\sin\alpha \sin\varphi - \sin \varphi) / (\cos\alpha \cos\varphi)]$$

where: ω – hour angle, α - angle of altitude, φ - latitude of the place, δ - angle of declination.

3. BLOCK DIAGRAM OF THE TRACKING SYSTEM

To change the azimuth and elevation position of the considered photovoltaic panel were used two bipolar stepper motors. Their control was achieved via a serial interface performed for this purpose (fig. 2).

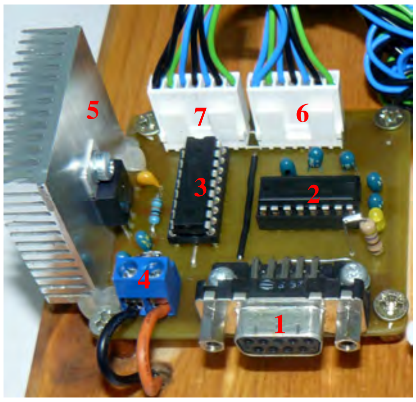

Fig. 2 General view of the serial interface to control bipolar stepper motors: 1 – serial connector RS232; 2 – MAX232; 3 – PIC16F627; 4 – power supply connector; 5 – L7805; 6, 7 –communication with motor's drivers.

This interface consists of: a specialized circuit (2) which acts as the computer adaptation level (12 VDC signal) to the microcontroller (3) (5 VDC signal); PIC16F627A microcontroller (3), ensures signal processing, execution of received orders and the motor operating program.

Voltage stabilizer (5) provides power to +5V to the microcontroller, adapter level and power to other specialized circuits on the motor drivers. Serial port connector (1) provides bidirectional communication with the computer. Motor drivers determine the direction of rotation of the motors and the number of steps (Fig. 3).

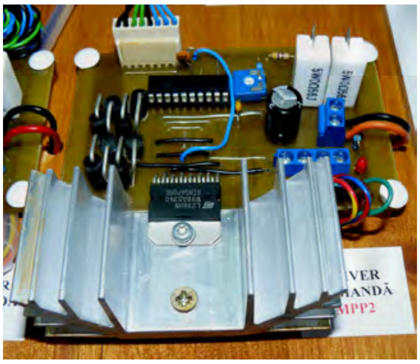

Fig. 3 Bipolar stepper motor driver

Azimuthal orientation program based on statistical meteorological data was done in C # development environment Visual Studio and provides the PV panel orientation, depending on the daily position of the sun. Serial communication module with PIC16F627A microcontroller provides data transmission from the computer to the serial interface.

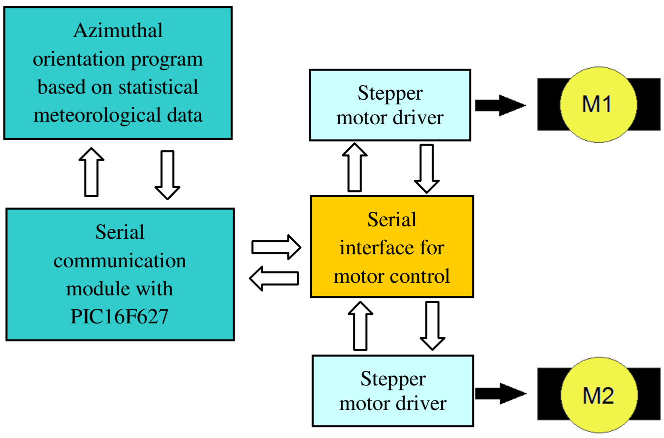

Fig. 4 Simplified block diagram of the achieved tracking system

Serial interface for motor control aims logical signal processing received from azimuthal orientation program based on statistical meteorological data. This module also communicates with bipolar stepper motor drivers.

Stepper motor driver includes a protection module and confirm to the serial interface for the motors control the fact that the stepp was made up. The general block diagram of the system of orientation is presented in fig. 4.

Azimuth tracking system operation is shown in Fig. 5 and includes functions related below.

- „*Latitude and longitude input*" - allows the user to enter manually geographic coordinates of where you install azimuth orientation system.
- „*Location selection*" - allows the user the choice of predefined locations. Depending on the option selected, the program will read in the database the latitude and longitude of the chosen location.
- „*Geographical data acquisition*„ - takes user input or database.
- „*Identification of the current date and time from the internet or local*„ - the program helps to identify the exact date, day and time to calculate accurate the solar day, depending on season and geographical location.
- „*Calculation of solar day, sunrise and sunset*„ - is a complex function that depends on the data entered and calculated, to determine the exact solar day and azimuth.
- „*Processing of data, performing calculations*„ - aims to prepare data into a eligible format for next function of the program.

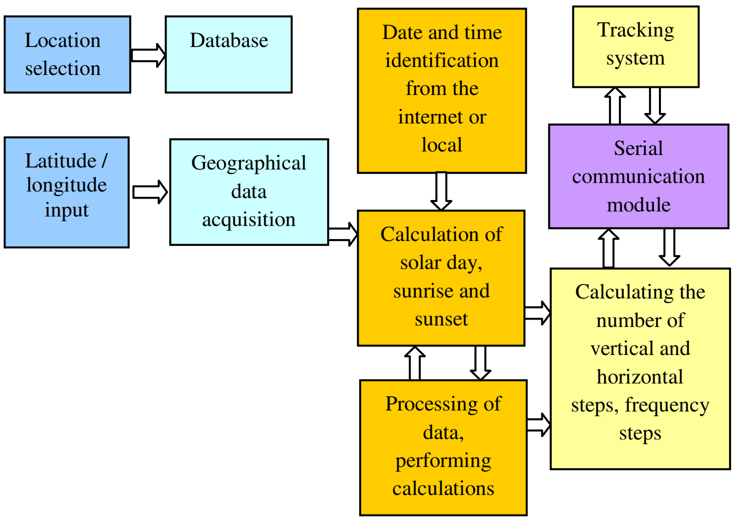

Fig. 5 Logical diagram for control the operating azimuth tracking system

▪ „*Calculating the number of vertical and horizontal steps, frequency steps*" - provides calculation of the steps to be performed by bipolar stepper motor that realize two axes orientation.

3. GRAPHICAL INTERFACE OF THE TRACKING SYSTEM

Azimuthal orientation program is based on the statistical weather data daily position of the sun. It uses a database, in text format, which contains the latitude and longitude of most cities in the world but there is also the possibility of introducing the geographical coordinates manually. As we know, latitude may be positive (north) or negative (south). Eastern longitude is positive and the west is negative. This fact led to the introduction of additional conditions and validation software for reading location database to prevent erroneous calculations. Graphical interface made and used for orientation photovoltaic panel is presented in fig. 6.

If the user chooses the "*Manual input of coordinates*", reading from the database is locked and vice versa.

The program automatically takes time and day from the computer or internet. The GMT has to be set according to the city that is supposed to be used the tracking system, otherwise the program will generate a warning.

Total number of steps are read from a file and the user has the right to modify / optimize the number of steps when changing the gear ratio.

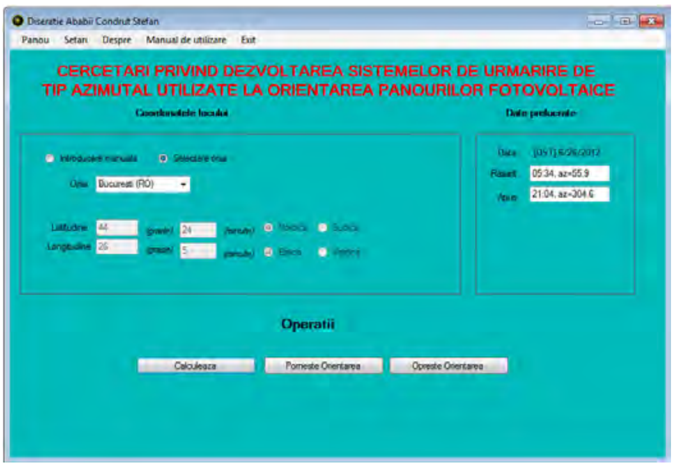

Fig. 6 Graphical interface of the tracking system

Function "Calculate", processes the input or selected data by the user, calculates summer time or winter if necessary, calculate solar day, the time at which the sun rises and sets.

Pressing "Start orientation" button, the program reads the current time and calculate the number of steps to be carried out depending on how much is left of that solar day.

The "Stop orientation" button resets the orientation program, stops communicating with the microcontroller and motors drivers, so orientation of the PV panel will be off.

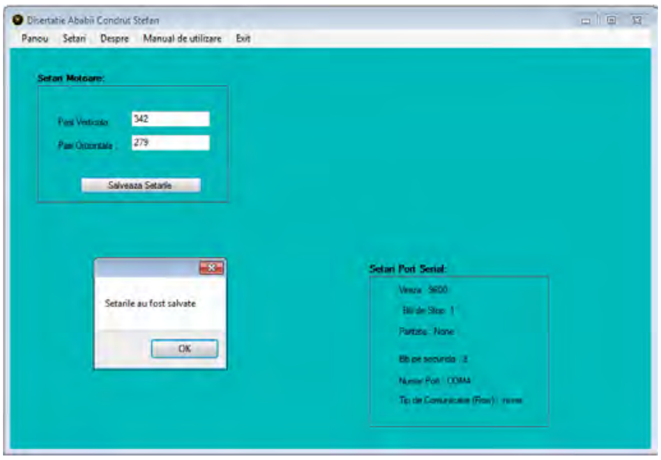

Fig. 7 Graphical interface of the tracking system - manually entering the number of steps of the motors

The program offers a menu with settings made for both stepper motors and settings to be made for USB-RS232 serial interface for proper operation of the program. These settings are written and read in a text file to be saved, and in case of using another computer, to be preserved. The "Save settings" file write values entered manually by the user (fig. 7).

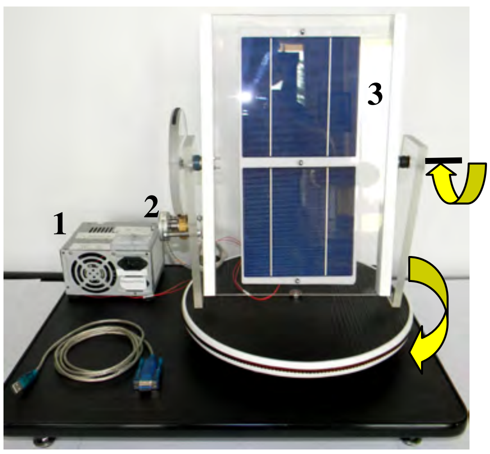

Fig. 8 General view of the realized tracking system:
1- control of the stepper motors; 2- stepper motor for altitude orientation; 3- PV panel.

An overview of the developed tracking system, as well its main parts are shown in Fig. 8. Details regarding the position of the stepp motor used for PV panel orientation on altitude are shown in Fig. 9. The box that includes controls of the stepper motors is shown in detail in Fig. 10.

From the motor drivers program, is signalized the altitude and azimuth orientation when engines are powered through two red LEDs positioned in the upper right of the box. It is also indicated the presence of communication between drivers and microcontroller stepper motors, with three LEDs *M1*, *M2* and *Microcontroller*.

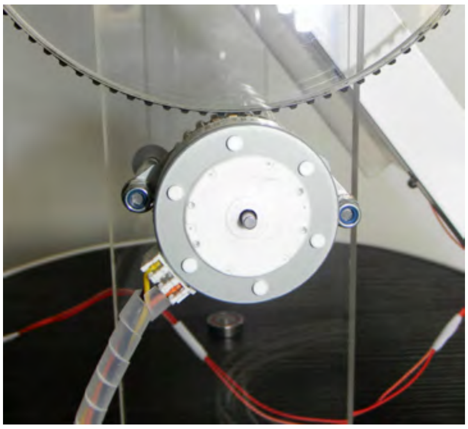

Fig. 9 Detail on motor positioning for altitude orientation

Through the two LEDs positioned at the lower left (24V drive motor operation) is confirmed the presence of supply voltage to stepper motors.

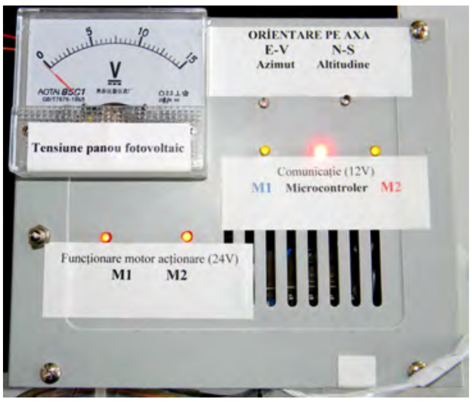

Fig. 10 Control box of the azimuthal tracking system

Is present and a voltmeter offering at any time the voltage provided by the PV panel (Fig. 10).

3. CONCLUSIONS

Orientation of the solar panels solar power plants is done, in most cases, by the help of the defined trajectories of the Sun. Through the use of stepping motors for orientation on two axes, azimuth and altitude, the positioning accuracy is increased.

Compared with the tracking systems that use photo-sensors, able to detect the position of the Sun in the sky, the ones that is dependent on statistical weather data are accepted as safer in operation.

For proper operation of the tracking system respectively precise orientation of PV panel after daytime continuous movement of the sun, following objectives were completed:

- PIC16F627A microcontroller programming;
- design and implementation of the program based on statistical weather data, in C #;
- implementation of a free database with most cities of the world with GPS coordinates, in the realized program;
- development with the help of Visual C# of the orientation algorithm;
- implementation of a automatic system for calculation of solar day, depending on the day, time, date and season;
- PV panel mouvement in the position for a new sunrise.

Tracking system can run in almost every geographic area in the world with the possibility, through graphical interface, to be introduced by the operator, the GPS coordinates of where the PV system will be exploited.

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About the authors

Lecturer Eng. **Constantin UNGUREANU**, PhD
"Ştefan cel Mare" University of Suceava
email: costel@eed.usv.ro

Graduated at the Stefan cel Mare University of Suceava, Faculty of Electrical Engineering and Computer Science, study program *industrial energetics*. Since 2000, after finishing of the university he started to work at the Stefan cel Mare University of Suceava, Faculty of Electrical Engineering and Computer Science, Electrotechnic Department. His research topic is solar energy conversion, unconventional actuators, insulation systems.

Eng. **Condruț-Ştefan ABABII**
EGGER Rădăuți, Romania
email: condrutz85@gmail.com

Graduated at the Stefan cel Mare University of Suceava, Faculty of Electrical Engineering and Computer Science, two study programs *Computers* and *Industrial energetics*. Since 2010, after finishing of the university he started to work at the EGGER Rădăuți, Romania. In 2012 he graduated a master program *Modern systems for energetic processes leading*.