Sun tracking system for photovoltaic batteries in climatic conditions of the Republic of Cuba

D D Gerra*, E V Iakovleva
Department of Electrical Engineering, Saint-Petersburg Mining University, 2, 21st Line, St Petersburg, 199106, Russian Federation

* E-mail: em88mi@gmail.com

Annotation. Today, the efficiency of solar power plants in the Republic of Cuba is low, despite the high level of technology development in this area. The article presents the results of the analysis of the potential of solar energy in the territory of the Republic of Cuba. This paper presents the results of experimental studies, the purpose of which is to increase the efficiency of using photovoltaic stations. The developed two-axis sun tracking system is described. This tracking system increases the conversion efficiency of solar energy into electrical energy in photovoltaic modules.

1. Introduction
Today, the share of electricity generated from renewable energy sources is increasing every year [1]. Wind turbines [2], solar photovoltaic stations, biothermal plants and tidal systems are widely used. This paper discusses a method for increasing the efficiency of solar energy capture by a photovoltaic panel.

In order to objectively assess the possibility of using solar energy, as well as the efficiency of using this energy source, it is necessary to conduct a comprehensive analysis of data on the total solar energy in a particular region [3]. To do this, conduct studies of the radiation regime in time, to determine the production of heat or electricity by a solar plant for one month, a season or one year, with further evaluation of its technical and economic indicators. For the analysis of insolation, existing data are used in real time using global system satellites, climate atlases, and field measurements of solar radiation directly at the facility.

As is known, the amount of solar radiation depends on latitude and varies from 6 kW / m² at the equator to 1.3 kW / m² at the pole. Figure 1 shows the intensity of solar radiation in the territory of Cuba by means of SUNY modeling, which has a high spatial resolution (1 x 1 km) and is obtained from satellite images.
The amount of solar radiation that falls on a horizontal surface of 1 m² in some regions of the Republic of Cuba in the summer months is comparable to the insolation values for the south of Spain and can be 6 kWh / m². The greatest flux of solar radiation occurs in the summer months - more than 5 kWh / m² per day in the middle zone of the Republic of Cuba (Figure 2). It should be noted that the intensity of insolation during the year does not fall below 4.8 kWh / m².

The foregoing indicates that the use of solar energy in the territory of the Republic of Cuba is appropriate. Since solar energy is a renewable energy source, solar systems with photovoltaic panels, which work on the principle of converting solar energy into electrical energy, will reduce the costs of traditional types of resources [5].

2. Development of a tracking system for the Sun

Flat photovoltaic modules convert both direct and scattered solar radiation, incident at any angle, and generate electricity, even when their receiving surface is not oriented directly towards the Sun.
Tracking in photovoltaic systems with flat photovoltaic modules is used to increase the generation of electrical energy received from the direct component of solar radiation [6, 7].

The Sun tracking system (solar tracker) is a complex of devices and mechanisms ensuring the optimum position of the receiving surfaces of photovoltaic panels relative to the Sun by following the course of the Sun across the sky. This increases the amount of solar radiation entering the receiving surface.

Today there are two main types of trackers: single and dual axis trackers. Single-axis trackers are adjusted every month or taking into account seasonal changes in the position of the sun. The single axis of single-axis trackers is used to track the daily movement of the Sun through the sky bridge. Dual-axis trackers eliminate the need for monthly adjustments: one axis tracks the movement of the sun per day, and the other axis tracks seasonal movement. A single-axis solar tracker improves solar radiation reception by about 25%, and a dual-axis tracker by about 40% (Figure 3) [8].

In this paper, the Azimut-Altitud type sun tracking system was chosen, since it is more efficient.

2.1. Experimental installation.
Sun tracking systems used with flat photovoltaic panels are required to ensure a decrease in the angle between the direction of the sun and the normal to the receiving (working) surface of the photovoltaic module. Due to this, the most complete use of all the incoming energy of the Sun is guaranteed and the amount of solar radiation entering the receiving surface of the photovoltaic modules during the same period of time increases [9].

This tracker control system (Figure 5) is designed to capture solar radiation in the direction from the east and west (left and right). The system determines how to move the panel so that it is aimed directly at the light source. A servo drive is used to drive the panel, since this type of drive is available in a wide range of sizes and can be scaled to fit the size of the panel.

On the photovoltaic panels of the experimental installation, there are various sensors - illumination, temperature, atmospheric pressure and relative humidity, which in real-time transmit information to the central microcontroller about the current state of the environment. The microcontroller, according to the developed program code, processes the received information.
In addition, the developed program code, implemented in the microcontroller, is reused to control the movement of servo motors, to track solar activity and measure various environmental parameters of interest for current research. After the software code calculates which sensor receives more sunlight, and if the difference is greater than a small threshold, the microcontroller sends a signal to the servo to change the position of the photovoltaic panel to position it in the direction of the light source. If the light value falls below a certain level for both sensors, then this mode is defined as night time and the panel moves east while waiting for the sun to rise.

The principle of operation of the experimental installation is presented in Figure 5.

![Figure 4. Experimental installation.](image)

**Figure 5.** Block diagram of the experimental installation.

2.2. Experimental results

Since all the data obtained from the sensors are processed in the microcontroller, and the information obtained is subsequently fed to a computer and processed in accordance with mathematical models in the Matlab software, the study determines the effectiveness of using sun tracking systems [10, 11]. According to the data collected by an experimental model (Figure 5) developed to study the electrical characteristics of solar tracking systems (CE) and stationary systems (SS) with photovoltaic modules...
in the same climatic conditions, it was found that the use of tracking systems increases the efficiency of using photovoltaic panels.

The results of experimental studies are presented in Table 1.

Table 1. The results of measurements of solar radiation for the month of May in the territory of the Republic of Cuba (SS-solar radiation, captured by the panel when using a two-axis tracking system, CE - solar radiation with a fixed installation of panels).

| Day  | CC, kW h/ m² | CE, kW h/ m² | (%)  | Day  | CC, kW h/ m² | CE, kW h/ m² | (%)  |
|------|-------------|-------------|------|------|-------------|-------------|------|
| 1-May| 2.002       | 2.891       | 30.75| 16-May| 4.525       | 5.655       | 19.98|
| 2-May| 5.792       | 7.638       | 24.17| 17-May| 4.657       | 5.117       | 8.99 |
| 3-May| 5.885       | 6.760       | 12.94| 18-May| 4.657       | 5.117       | 8.99 |
| 4-May| 4.653       | 5.406       | 13.93| 19-May| 4.254       | 5.439       | 21.79|
| 5-May| 4.722       | 5.155       | 8.40 | 20-May| 7.096       | 8.42        | 15.72|
| 6-May| 6.326       | 8.041       | 21.33| 21-May| 4.657       | 5.117       | 8.99 |
| 7-May| 4.657       | 5.117       | 8.99 | 22-May| 3.525       | 3.955       | 10.87|
| 8-May| 5.498       | 6.169       | 10.88| 23-May| 4.254       | 5.439       | 21.79|
| 9-May| 7.096       | 8.420       | 15.72| 24-May| 6.936       | 8.29        | 16.33|
| 10-May| 6.735       | 7.675       | 12.25| 25-May| 5.657       | 6.117       | 7.52 |
| 11-May| 4.525       | 5.655       | 19.98| 26-May| 7.256       | 8.547       | 15.10|
| 12-May| 6.329       | 7.809       | 18.95| 27-May| 5.184       | 6.536       | 20.69|
| 13-May| 6.218       | 7.559       | 17.74| 28-May| 6.973       | 8.936       | 21.97|
| 14-May| 5.873       | 6.301       | 6.79 | 29-May| 4.153       | 5.534       | 24.95|
| 15-May| 5.885       | 6.768       | 13.05| 30-May| 3.153       | 4.534       | 30.46|

Average value: CC= 5.30, CT= 6.34, ΔE=17%

From the experimental results it can be seen that, on average, the amount of captured solar radiation is 17% higher with the use of the sun tracking system than with a fixed arrangement of solar panels.

3. Conclusion

Research data on horizontal radiation show that solar radiation captured by a solar panel can be increased by introducing more advanced technologies, such as tracking systems for the brightest object, as this will increase the amount of electricity generated in the country by 10-30%, and also reduce the cost of production of 1 kW of photovoltaic energy.

These results confirm that solar tracking systems are an alternative way to increase the efficiency of capturing and further converting solar radiation in photovoltaic power plants in the Republic of Cuba.

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