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SUN TRACKING PHOTOVOLTAIC SYSTEM

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ABSTRACT

The purpose of this paper is the design and realization of a prototype system for tracking the position of the sun, with two axes of rotation. The operating principle of the device is based on changing the position of the photovoltaic modules in the direction of the sun's rays, which maximizes the production of electricity. Solar panels with automatic adjustment according to the position of the sun are an innovative solution for optimizing the use of the solar energy. The promotion and use of solar energy is essential in our efforts to protect the planet and ensure a sustainable future.

Keywords: solar energy, photovoltaic panel, Arduino, automatic tracking system

INTRODUCTION

Energy is the key driver for humanity's development aspirations. It is used every day to fulfill people's wishes and ambitions, thus becoming an indispensable factor. The importance of solar energy cannot be underestimated. The benefits obtained by using this inexhaustible and ecological source are invaluable not only from a financial point of view, but also from the perspective of public health and environmental protection. Every year, more and more companies and individuals realize the advantages of using solar energy and invest in complex systems that can transform this energy into heat or electricity, depending on their specific needs.

However, it is important to note that the use of solar energy is not only a technically and economically viable solution, but also an environmentally responsible choice. Solar energy is an inexhaustible and ecological source that does not produce harmful emissions or contribute to climate change. Therefore, the promotion and use of solar energy is essential in our efforts to protect the planet and ensure a sustainable future.

In figure 1 it can be seen that more than 50% of our entire country benefits from an annual energy flow of 1300 kWh/m2/year. This aspect is one of the best reasons for the development of technologies and equipment that use solar radiation [1].

In order to make the energy absorbed by the photovoltaic panels more efficient, there is a need for orientation/guidance systems called with which the amount of captured solar energy can be maximized. The automatic guidance / orientation devices (mono-axial or bi-axial), which adjust the position of the solar panel by following the movement of the sun during the day, are part of the subassemblies specific to photovoltaic panels.

As a rule, solar panels are operated by electrical, pneumatic or hydraulic systems.

Technologies for concentrating solar energy use special devices to capture sunlight, in order to retain a larger number of photons for the production of electricity. Solar concentrators are devices that work on the principle of focusing sunlight. This technology lenses or curved mirrors, to focus a large amount of sunlight on a small area of photovoltaic cells to generate electricity [3].

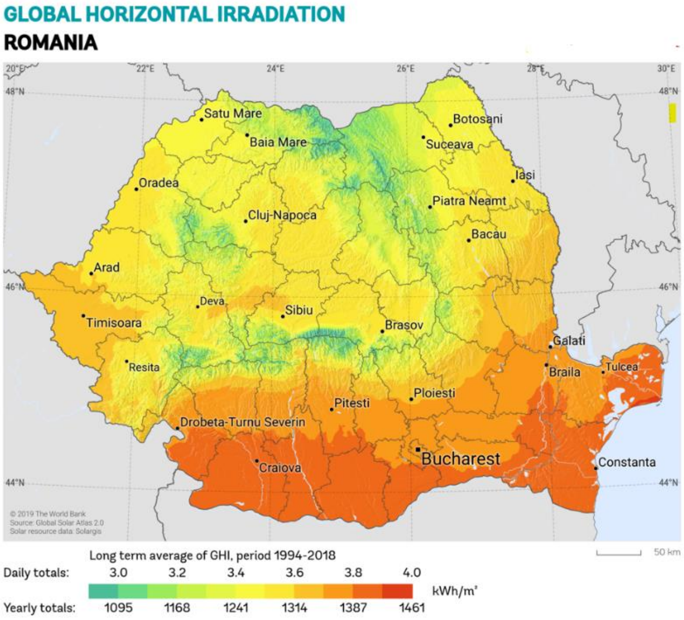


Figure 1. *Solar radiation map in Romania* [5]

Figure 2. *Solar collector* [6]

A solar cell (also called a photovoltaic cell) is an electrical device that converts light energy directly into electricity through the photovoltaic effect. It can generate and sustain an electric current without being connected to an external voltage source. To generate useful power, several cells must be connected to form a solar panel, also known as a photovoltaic module [4]. The diagram of the equivalent circuit of a solar cell is presented in Figure 3.

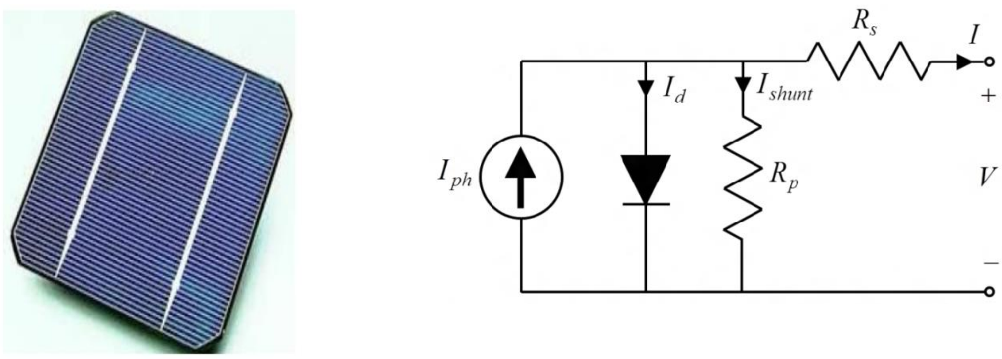
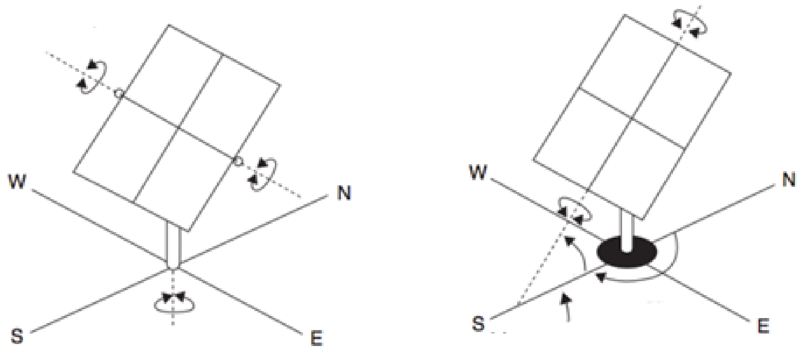


Figure 3. *Photovoltaic cell* [6]

PHOTOVOLTAIC PANEL POSITION CONTROL SYSTEM DESIGN

A system for automatically adjusting the position of a photovoltaic panel detects the position of the sun and moves accordingly. There are two main types of such systems for photovoltaic panels, one-axis and two-axis (Figure 4).

The single axis can change the tracking angle in one direction as the day progresses. The dual-axis one moves from east to west as the sun rises and sets each day, but it can also adjust in a north-south direction as the sun's position changes throughout the year. The efficiency of such a photovoltaic panel is up to 25%-30% higher than a fixed panel [5].



a) b)

Figure 4*. Automatic regulation systems of photovoltaic panels* [5]

a) with one axis; b) with two axes

The block diagram of the solar tracking system is presented in Figure 5.

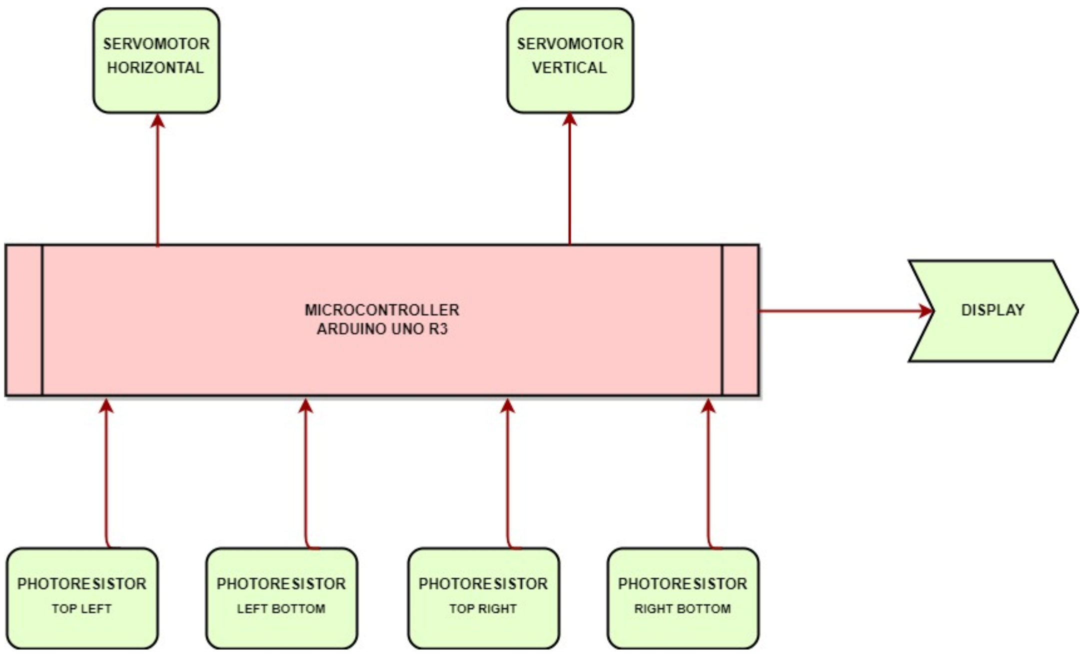


Figure 5*. Block diagram of the solar tracking system*

Photoresistors are light-sensitive electrical devices that have the ability to vary electrical resistance depending on the intensity of light falling on their surface. Their operation is based on the photoelectric effect, which consists in changing the electrical conductivity, more precisely, when a photoresistor is exposed to light, photons are absorbed by the semiconductor material, which causes the electrical resistance to decrease.

The composition of a photoresistor is shown schematically in Figure 6.

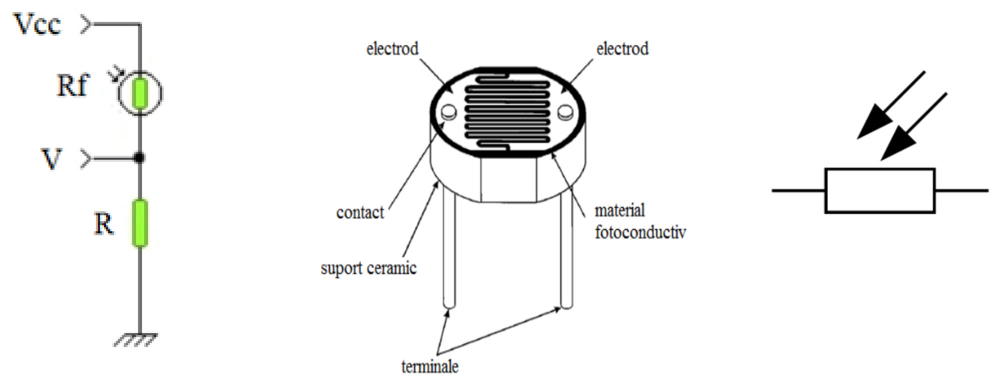


Figure 6. *Connection in the circuit, structure and symbolization of the photoresistor* [2]

Arduino Uno R3 is an open-source development board, flexible and easy to use, It is based on an Atmega328P microcontroller and has14 digital ports and 6 analog ports, which allow the connection of various sensors and peripheral devices, as well as communication with other systems via USB, I2C or SPI interfaces. One of its outstanding features is the Arduino programming interface, which offers a multitude of libraries and code examples, easy to understand and adapt for various applications (Figure 7).

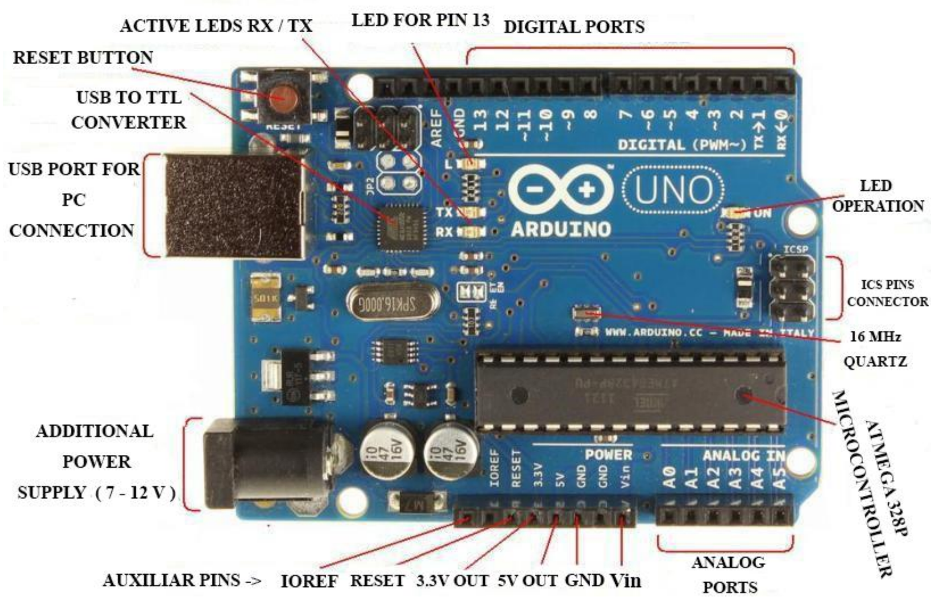


Figure 7. *Arduino Uno R3 development board* [7]

The servomotors used are model SG90 and consist of an electric motor coupled with a position feedback system, which allows precise control of the movement, represented by an internal potentiometer, used to monitor and report the current position of the motor shaft. It is controlled by pulse width modulation (PWM signal), with a duty cycle between 600μs and 2400μs and a period of 20ms (50Hz).

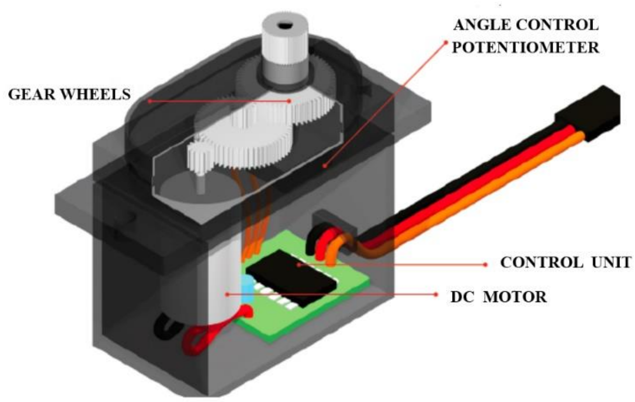


***Figure 8**. Servo motor SG90* [7]

For the display part, the I2C display is a very good option. It uses the I2C (Inter-Integrated Circuit) communication protocol. The I2C display consists of an array of pixels or segments and is controlled by an integrated controller. The ability of this I2C display is to communicate via the bus that allows bidirectional data transfer between the control device and the display. These displays can display text, numbers, symbols or images, depending on the device's specifications.

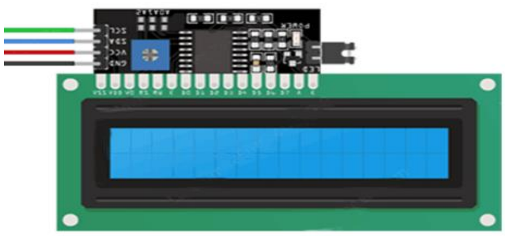


***Figure 9**. I2C display* [7]

SYSTEM IMPLEMENTATION

The electrical diagram of the system is presented in Figure 10.

The logic diagram of the program for controlling the position adjustment system, which will be implemented in the Arduino platform [3], is presented in Figure 11.

Figure 12 shows an image with the physical implementation of the photovoltaic panel position regulation system.

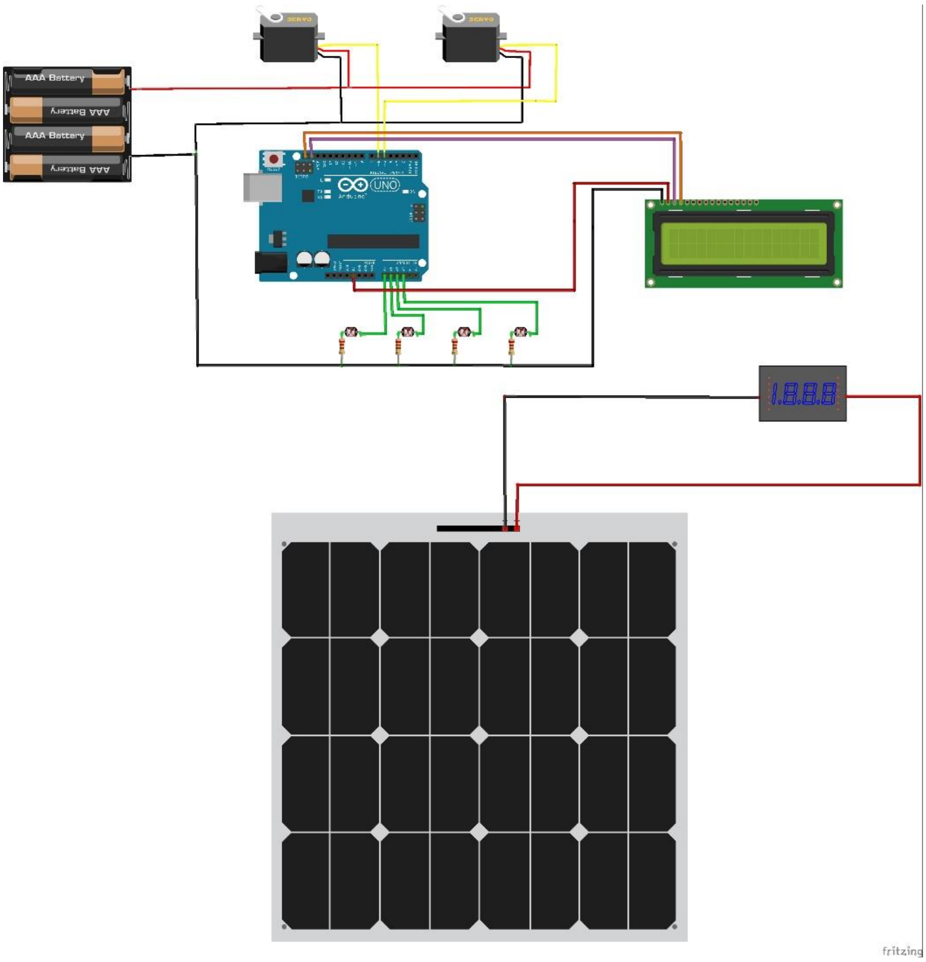


***Figure 10**. Electrical diagram of the system*

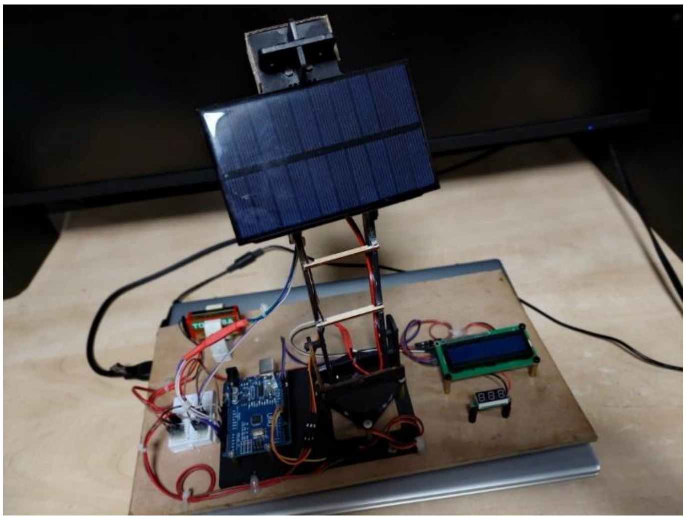


***Figure 12**. Physical implementation of the photovoltaic panel position regulation system*

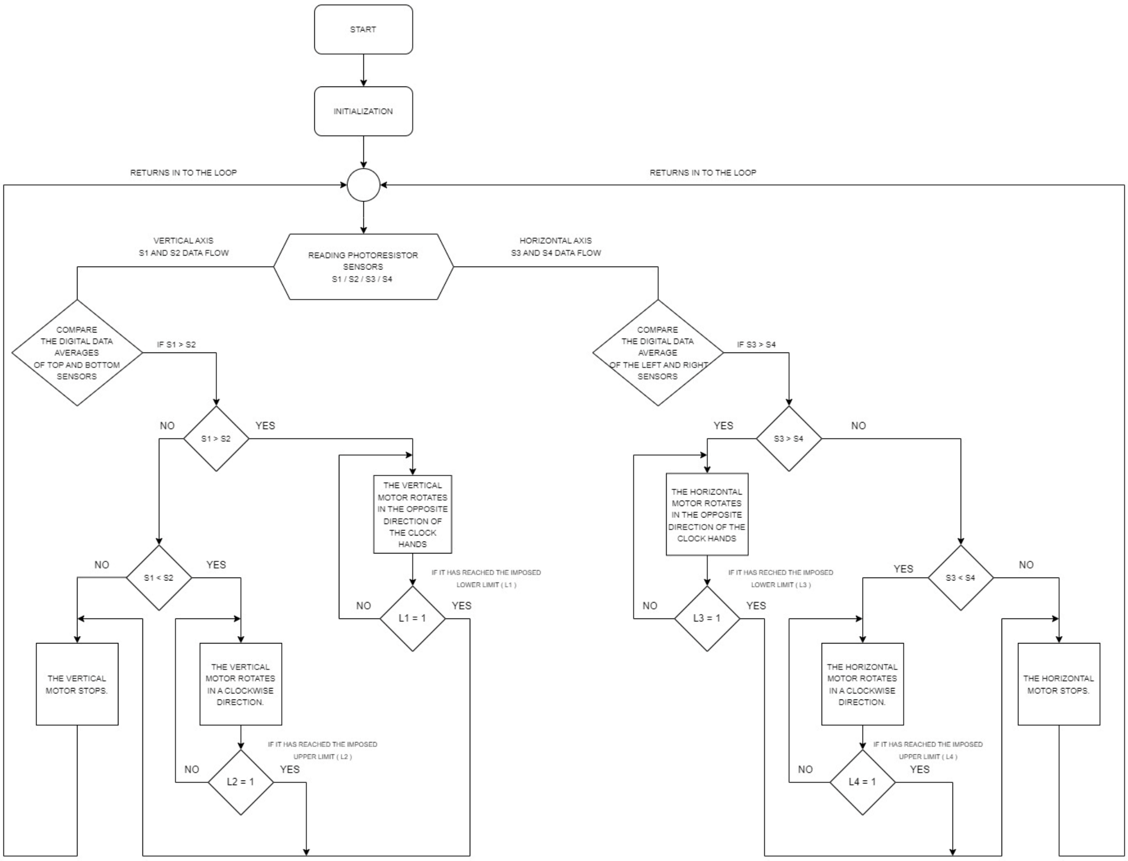


Figure 11. *Logical scheme of the program to control the position adjustment system*

The efficiency of the photovoltaic panel is calculated by relating the electrical energy produced by the panel to the light energy incident on the surface of the panel. Thus, we will need the following information: the nominal production of the panel (expressed in Watts) - represents the maximum power that the panel can produce in standard weather conditions; the surface of the panel (expressed in square meters - m^2) which represents the total size of the panel. In the present case, the photovoltaic panel is 6 cm wide by 11 cm long; solar radiation incident on the panel, i.e. the amount of light energy hitting the surface of the panel. It varies by location and time of day/year. Thus, according to the solar radiation map in Romania, the solar radiation is 3.6 kWh/m^2.

The light energy incident on the panel (expressed in watts - W) is of the form:

$$E = R \cdot A \tag{1}$$

where E is the electrical energy produced by the panel (expressed in W), R is the solar radiation incident on the surface of the panel (expressed in watts per square meter - W/m^2) and A is the area of the panel (expressed in square meters - m^2). The relationship for the electrical energy produced by the panel is:

$$E = P \tag{2}$$

where E is the electrical energy produced by the panel (expressed in watts - W) and P is the nominal output of the panel (expressed in watts - W).

To calculate the efficiency of the two-axis panel (expressed in percentages - %), we will use the relationship:

$$\eta = (E / R) \times 100 \tag{3}$$

where η represents the efficiency of the photovoltaic panel (expressed in percentages), E represents the electrical energy produced by the panel (watts) and R represents the incident solar radiation on the surface of the panel (W/m^2).

So, the efficiency of the two-axis photovoltaic panel with the dimensions of 11 cm long and 6 cm wide, and with a maximum voltage of 5.2 V and a maximum current of 2.1 A, is about 30.3%. This represents the conversion percentage of incident light energy into electrical energy produced by the panel.

CONCLUSIONS

Solar panels with automatic adjustment according to the position of the sun are an innovative solution for optimizing the use of this type of energy. The advantages of using solar panels with automatic regulation are: maximizing efficiency; cost reduction both by the fact that sunlight is used, but also by reducing maintenance costs, because they are designed to work automatically and limit human intervention to a maximum; reducing the impact on the environment by reducing pollution; improving performance by increasing reliability and reducing the failure rate; improving flexibility through the ability to adapt to weather changes and to the daily and annual variation of the sun's position, which makes them suitable for use in a variety of applications.

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