Uniaxial Sun Tracking System

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Abstract. The paper analyzes ways to use alternative sources of electricity, which are becoming increasingly relevant, attractive and affordable in domestic and industrial use. The paper considers the principle of operation of solar trackers; advantages and disadvantages in everyday life and industry. Increasing the efficiency of solar modules is the main task of all researchers working in this direction. To date, the efficiency of such devices ranges from 15 to 25%. The percentage is very low. Solar panels are an extremely capricious device, the stable operation of which depends on many reasons. The main factors that affect performance include: solar panel base material, orientation of solar flow reception, overheating of installations. By meeting all the research requirements and, if possible, installing the panels in the desired position, you can get solar panels with high efficiency. It is high, not maximum. The fact is that the calculated, or theoretical efficiency, is a value derived in laboratory conditions, with average parameters of daylight duration and the number of cloudy days. In practice, of course, the percentage of useful action will be lower.

1. Introduction

Energy independence, which provides the owners of houses, farms and remote from the networks of centralized energy supply of buildings, the use of solar panels, is becoming more realistic. Increasingly, solar panels are used as an autonomous, most independent source of energy supply. The main practical use of solar panels was to power orbital satellites and other spacecraft, and today most photovoltaic modules are used to generate electricity in the home and for industrial companies.[9]. Solar power plants are increasingly entering the daily lives of residents of different parts of our country and many other countries. In order to increase the efficiency of the use of solar panels, designers and engineers are developing new devices and devices, one of which is a solar tracker.

2. The purpose of the article

The use of trackers to increase the efficiency of solar panels by 45% and increase the amount of electricity produced. Due to the increase in the productivity of a single panel, there is no need to install additional panels, which in turn reduces the cost of the entire set of solar power plants.

3. Materials and Methods

The main element of the photovoltaic system are photovoltaic cells, which are connected to solar panels. The solar photovoltaic cell is made on the basis of a plate made of a semiconductor material, such as silicon. Areas with p- and n-conductivity types are formed in the plate.

As a method of creating these areas is used, for example, a method of diffusion of impurities or a method of building one semiconductor on another. Then the lower and upper electrical contacts are made, while the lower contact is continuous, and the upper is made in a cloud of comb structure (graceful strips combined with a wide busbar) [1].

The main material for solar cells is silicon. Silicon is one of the most studied materials in nature, and the second most common after oxygen. Silicon-based photovoltaic cells make up about 85% of all solar panels issued [14].

To develop the tracker, I used solar cells made of "single crystal silicon". The efficiency (efficiency) of these elements was 10% - 15%.

The advantages of installing a tracker can be formulated as follows:

1. The efficiency of solar panels increases by 40-45%. The increase is achieved due to the fact that the most efficient operation of the panels occurs when the sun's rays fall at an angle of 90 * on the photocells of the panel;

2. Due to the installation of the tracker, the efficiency of solar panels increases significantly, the amount of electricity produced increases.

3. Due to the increase in productivity of a single panel, there is no need to install additional panels, which in turn reduces the cost of the entire set of solar power plants.

In essence, a solar tracker is a comprehensive system that tracks the location of the sun.

In order to perform this task, the tracker must perform the following functions:

1. Determine the location of the sun relative to the solar panel;

2. Move the solar panel to the position where the absorption of sunlight will be maximum.

One of the options to increase the energy produced by solar panels without the addition of solar panels is the device of the solar controller with the technology "Maximum Power Point Tracker" (MPPT) - tracking the point of maximum power (MPRT) of the solar battery [1].

A conventional MPPT controller constantly monitors the current and voltage of the solar cell multiplies their values at which the power of the solar battery will be greatest. The integrated processor also monitors the stage of charge of the battery (charging, saturation, equalization, maintenance), and based on this determines what current must be given to it. At once the processor can give commands for indication of characteristics on the board (if available), data storage, etc. The point of maximum power can be calculated by different methods, therefore, there are many ways to find the point of maximum power (MRRT) [2].

The location of the Sun is the responsibility of an electronic system consisting of a GPS receiver that determines the location of the sun at the location of the solar power plant, as well as the time of day. Depending on the signal received from the satellite of the GPS-navigator system, the electronic system gives one or another command to the system of moving solar panels [4].

The servo motor is installed in the panel movement system, which allows to change the direction of rotation of the shaft, which allows to move the panel in different directions. The design of the movement system can be of different types, so solar trackers are divided into two types.

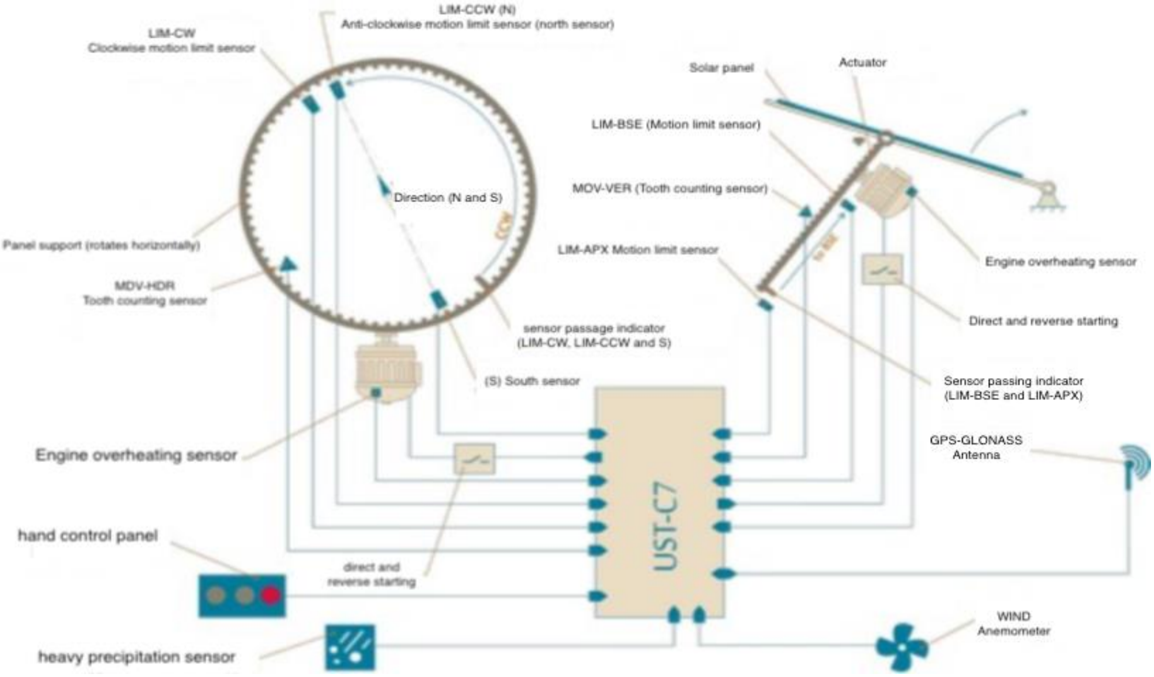


Figure 1. Scheme of the panel movement system.

The tracker scheme is simple and compact. To determine the position of the sun, two photoresistors are used. The motor is connected according to the H-bridge scheme, which allows to switch the current up to 500 mA at a supply voltage of 6-15V. In the dark, the device is also operational and will turn the motor to the brightest light source [2].

The diagram shows that the servomotor is driven at different values at the outputs of the OP IC1a and IC1b.

Table 1. Truth table

Output IC1a	Output IC1b	Servo motor status
Low.	Low.	Stopped
Low.	High.	Forward*
High.	High.	Stopped
High.	Low.	Back*

* depends on the connection of the servomotor

This type of circuit is not very practical, as it requires a lot of time to solder the elements and etch the circuit board. Therefore, there is an easier option to assemble a solar tracker using the Arduino UNO microcontroller, programming it to rotate the solar panel.

4. Results

The largest allocated power of solar panels is calculated by the formula:

$$P = U_p \times I_p$$

where Up is operating voltage, Ip is operating current

The maximum voltage that can be emitted by a solar panel is 12 V, the operating current for this type of panel is 250 mA.

During the development of the tracker control, the volt-ampere characteristics of the solar battery (SAT) were taken in different lighting conditions: in bright sunlight, gloom, different angles of inclination [12].

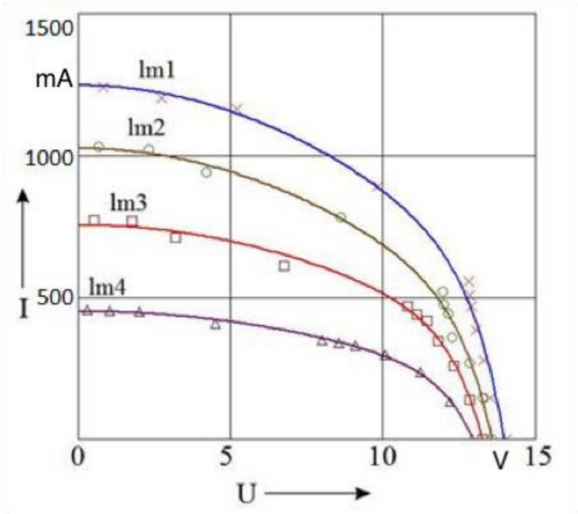
We present tables of dependences of the I – V characteristics at bright solar radiation and various criteria, where lm1 is the plane of the solar battery perpendicular to the Sun; lm2 - the plane of the solar battery is perpendicular to the Sun and the battery is located behind the glass; lm3 - between solar radiation and the plane of the solar battery 60 degrees; lm4 - between solar radiation and the plane of the solar battery 60 degrees and the battery is located behind the glass [18].

Table 2. I-V characteristics of the solar panel under conditions lm1 and lm2

R, Om	Lm1			Lm2		
	U,V	I, мA	P, мW	U, V	I, мA	P, мW
6.6	0.82	1240	1020	0.68	1030	700
22.7	2.73	1200	3280	2.32	1020	2370
44.7	5.2	1160	6050	4.2	940	3950
110.4	9.84	890	8770	8.62	780	6730
230	12.82	560	7150	11.95	520	6210
252.7	12.85	510	6530	12	470	5700
274.7	12.89	470	6050	12.14	440	5370
340.4	13.05	380	5000	12.26	360	4420
477	13.3	280	3710	12.85	270	3460
922	13.5	150	1980	13.27	140	910
∞	14	0	0	13.5	0	0

Table 3. I-V characteristics of the solar panel under conditions lm3 and lm4

R,Om	Lm3			Lm4		
	U, V	I, мA	P, мW	U, V	I, мA	P, мW
6.6	0.51	770	390	0.3	450	140
22.7	1.75	770	1350	1.03	450	470
44.7	3.18	710	2260	2.01	450	900
110.4	6.74	610	4110	4.5	410	1830
230	10.8	470	5070	8	350	2780
252.7	11.02	440	4810	8.25	330	2690
274.7	11.45	420	4770	9.1	330	3010
340.4	11.8	350	4090	10.08	300	2980
477	12.63	260	3340	11.23	240	2640
922	12.83	140	1790	12.2	130	1610
∞	13.2	0	0	12.9	0	0



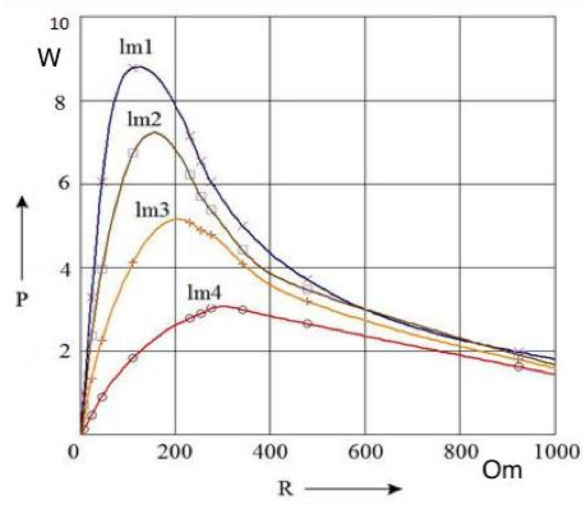


Figure 2. I – V characteristics of the panel at different illumination

Figure 3. Dependence of P on load resistance P (R)

In bright sunlight, in the case of lm1, the load of 110.4 ohms shows the highest power, but for the main experiment and for further operation of the device, set the load to 230 ohms. With the presented load, the tracker will emit sufficient electricity generated in cloudy conditions, and it will be even better to respond indoors under artificial lighting [19].

The removed dependences (especially the calculated dependence of the SAT power on the resistance) demonstratively demonstrate that, depending on the load, the operating point of the solar battery can be shifted to the region of minimum or even zero production. As a result, the interaction of the solar cell with the load is an important point.

In photoresistors, the resistances change with the change in light intensity, so they must be connected in such a way that the changes in the resistance are converted into a voltage signal that enters the Arduino. The servomotor is controlled via one of the PWM outputs in the Arduino [16].

5. Discussion

The best method is software control of the rotation mechanism. Calculating the position of the Sun at a set time, special software transmits this information to the power plant, and taking into account the converted data, the tracker sets the angle of the entire field of solar panels and orients them in the right direction [15].

Any of the management techniques is suitable for different conditions. For personal use, a manual method of control with a change of angle twice a year (spring and autumn) is suitable. It is economically purposeful to put trackers for several panels or collectors. For large power plants or fields with solar panels, only the software method of tracker control is relevant.

As a result of the development of the software part of the device, various variants of work were made. For example, one such option was to find the maximum illuminance, when the servomotor shaft moved first 10 degrees and read the voltage of the solar cell, and then 1 degree in the area around the expected maximum for the most accurate search. This option of finding the maximum can be called two-stage, as we are looking for a maximum of two passes. This version of the work gave great search accuracy, but spent a lot of energy [11].

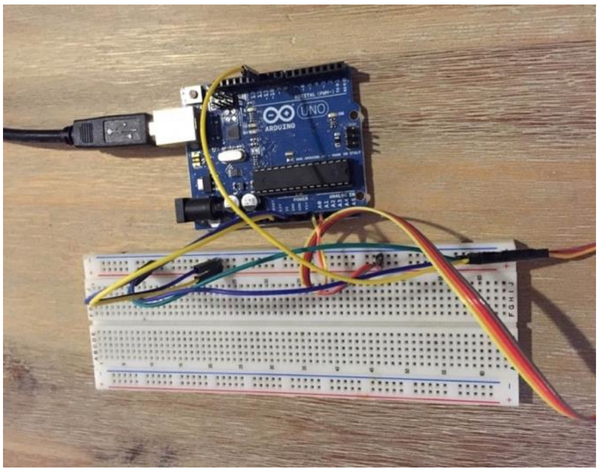


Figure 4. Connecting components to the Arduino board.

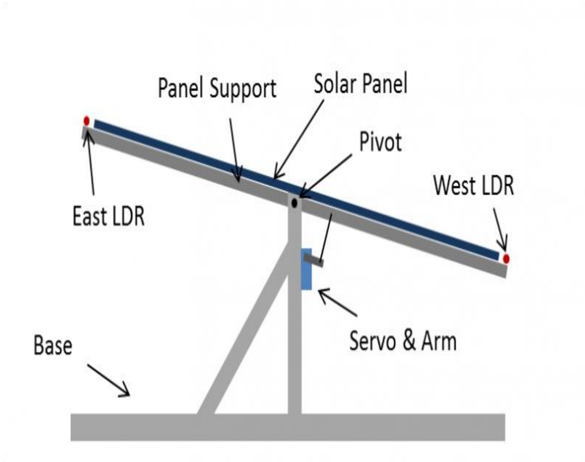


Figure 5. Making a uniaxial base.

The equipment of the solar battery with an automatic rotary mechanism generates certain requests for mechanics, electronics and automatic control systems. Thus, for adequate tracking of the position of the sun, the installation must have two degrees of freedom. This is realized through the use of two executive links - a movable disk and a movable platform.

Based on the development of existing structures, we offer the following adaptation of the platform for automatic tracking of the sun, in Figure 5, which shows the equipment consisting of a fixed base (1), two racks (2), a platform with a solar battery (3) driven by a servomotor (4). To provide feedback, the device also includes several light level sensors [9].

The servomotor must be selected depending on the size of the solar panel. The panel used in this example is small and relatively light; therefore, a small servo motor is used, which takes power from the Arduino. For a larger servomotor (anything above 9 grams), you will need to power the servomotor externally with additional power supplies, as the Arduino does not have enough potential for this.

Ideally, the pivot point should be placed in the center of gravity of the panel support. Two servomotors can be used for heavier panels, one on each side of the panel. You can then duplicate the servomotor code in the software so that both servomotors are assigned the same commands and they will move together to power the panel.

Conclusions

In the first section of my research work, the main types of solar panels, their structure, principle of operation and calculations for the single-crystal solar panel used to make a solar tracker were considered. The use of solar trackers allows to solve problems of any level in the consumer segment, it is to provide electricity to the equipment installed in the country, and comprehensive autonomous power supply of cottages, including landscaping of surrounding areas, as well as heating, pool heating and air conditioning.

Autonomous power supply systems based on solar trackers can be used as the main source of renewable energy, and as a backup, it is reliable for your home.

The volt-ampere characteristics of the solar battery were studied and presented, on the basis of which it is possible to draw a conclusion about the expediency of using the device in connection with energy efficiency, which is clearly seen in the graphs of the presented work.

An important step in the study was to write a program for the Arduino UNO microcontroller, eliminate all the shortcomings for the correct operation of the board and connect all the components according to the schematic diagram of the device. A frame was made to hold the solar panel.

As a result of research, I developed a model of a micro power plant controlled by a solar tracker, the actuator of which is a servomotor. Tasks were set, the alternation of which helped to achieve the main goal of the work:

1. Selected solar cell with battery and charge controller. Uniaxial and biaxial trackers for solar control are considered.

2. Developed an electrical schematic diagram of the device, which helped to understand what the minimum set of elements should consist of a control uniaxial tracker. The selection of elements was carried out, the implementation of software control of the tracker operation was described.

Throughout the study, a model of the solar control system was created, using a uniaxial tracker that searches for the position of maximum illumination, and the solar panel provides the necessary voltage to power electronic devices.

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