New Approach to Increase the Solar Panels Energy Parameters

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Abstract

One of the most important issues that need to be solved in the solar energy area is to get the maximum possible energy during the day from panels that convert solar energy into electricity, depending on the position of the sun in the sky. For that, it is proposed to ensure the falling sunray on the panels at right angles by changing their position around two horizontal axes placed perpendicular to each other in proportion to the current value of energy received from the solar panels. Controlling the position of the panels in this way allows always get the maximum possible energy from the falling sunray, regardless of the location on the Earth's surface, the seasons, and the hours of the day.

Keywords: solar beams, solar panels, electrical energy, measurement of power, maximum energy, operating controllers.

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Günəş panellərinin energetik göstəricilərinin artırılmasına yeni yanaşma

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Xülasə

Günəş energetikasında həll olunması vacib məsələlərdən biri Günəşin səmadakı mövqeyindən asılı olaraq günəş enerjisini elektrik enerjisinə çevirən panellərdən gün ərzində daim maksimal mümkün olan enerji əldə etməkdir. Bunun üçün günəş panellərindən alınan enerjinin cari qiymətinə mütənasib olaraq onların vəziyyətini biri-birinə perpendikulyar yerləşdirilmiş iki üfüqi ox ətrafında dəyişməklə günəş şüalarının panellərin üzərinə daim düz bucaq altında düşməsini təmin etmək təklif olunur. Panellərin vəziyyətinin bu qaydada idarə edilməsi Yer səthində yerləşdikləri məkandan, ilin mövsümlərindən və günün saatlarından asılı olmayaraq günəş şüalarından daim maksimal mümkün olan enerjini əldə etmək imkanı yaradır.

Açar sözlər: günəş şüaları, günəş panelləri, elektrik enerjisi, gücün ölçülməsi, maksimal enerji, idarəedici kontrollerlər.

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Новый подход к увеличению энергетических показателей солнечных панелей

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Аннотация

В статье предлагается метод, как в зависимости от прямого значения полученной электрической энергии изменять положение солнечных панелей, преобразующих солнечную энергию в электрическую: вокруг двух расположенных перпендикулярно относительно друг друга горизонтальных осей обеспечивается падение лучей на поверхность панелей под прямым углом, благодаря чему получают максимально возможную энергию в течение дня. Такой подход создает возможность независимо от их географического расположения на местности, времени года и суток постоянно получать максимально возможную энергию от лучей Солнца.

Ключевые слова: солнечные лучи, солнечные панели, электрическая энергия, измерение мощности, максимальная энергия, управляющие контроллеры.

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Introduction

There are various devices that can convert solar energy into electricity with the help of solar panels placed on stationary supports [1]. One of the disadvantages of these devices is that they can efficiently convert energy in just one period of daylight (when the sunrays fall on the panels at an angle of about 90^0). Furthermore, it is impossible to take into account the effect of changes in the trajectory of the sun in the sky depending on. It is known that the energy conversion efficiency of solar panels in any place on Earth depends on the current position of the sun in the sky (angle of falling sunbeams), changes in the trajectory, weather temperature, as well as the seasons. Figure 1 shows a diagram of the change in the position of the Sun during the day for Berlin, Germany, Figure 2 for Cairo, Egypt [2], and Figure 3 for Baku, Azerbaijan.

In the diagrams, the NE is standing for the northeast, SE for the southeast, SW for the southwest NW for the northwest, and N, W, and S for the corresponding poles. It is clear from these diagrams that the trajectory of the Sun in the sky during the day in different places on Earth also varies significantly depending on the season. (This expression is conditional in meaning, but in fact, the process is related to the rotation of the Earth around the Sun). Therefore, in order to obtain maximum energy, this factor must be taken into account in the operation of devices that convert solar energy into electricity.

More efficient devices are devices that are placed on movable supports and allow the program to change the position of the panels depending on the position of the Sun in the sky [3-5]. Such devices can only work effectively in areas close to the equator, where the sun rises in the east and sets in the west because in these areas the falling sunray always falls at an angle of about 90^0 to their surface during a bright day due to the rotation of the panels around the horizontal axis.

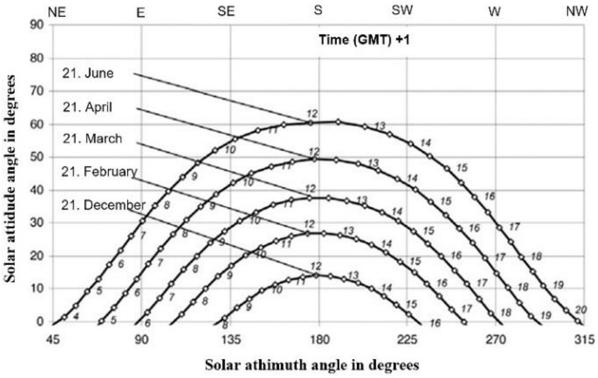

Figure 1 – Solar Position Diagram for Berlin, Germany [2]

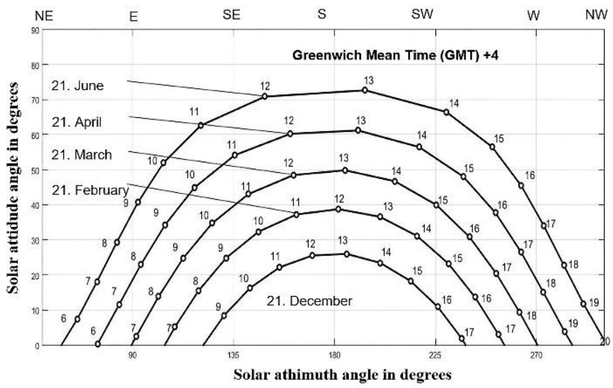

Figure 2 – Solar Position Diagram for Cairo, Egypt [2]

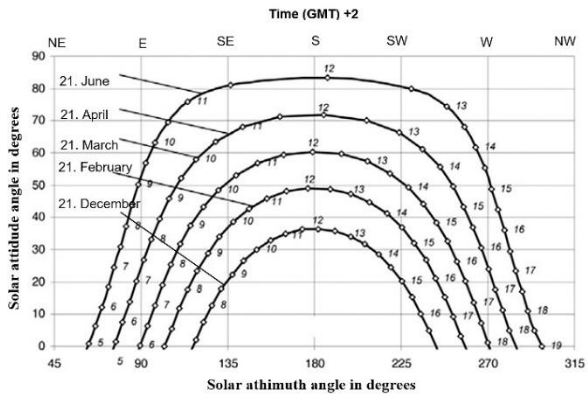

Figure 3 – Solar Position Diagram for Baku, Azerbaijan

In areas far from the equator, such an approach is ineffective because the Sun's trajectory in the sky changes from season to season, as it is not possible to direct light rays at right angles to the surface of the panels during the day.

Another device uses 5 photocells placed at different angles in 4 planes that record the position of the Sun in the sky to control the position of the panels based on the principle of azimuth and zenith tracking [6].

Another solar tracking system uses a different signal from the two: static and comparable signals from motor transmitters, and the position of the panels is controlled by azimuth and zenith [7].

The object of the research

In the operation of these devices, the condition of the panels is controlled not in direct proportion to the current value of the energy obtained from them, but in proportion to any indirect indication.

The proposed device allows for overcoming this deficit. This means that it is possible to reach an amount of sunray which is falling to about $90^0$to the panel, by changing the position of the solar panels around both the 1st and 2nd horizontal axes perpendicular to it, depending on the geographical position of the place, the seasons, the change in energy received and the position of the Sun in the sky.

In our research, samples of solid carbon-fiber-reinforced plastics with and without fiberglass sublayer were subjected to flame electric discharge treatment. The choice of these materials is related to their practicality for use as a substrate. They are lightweight, weather resistant, and affordable. To obtain durable conductive coatings,

Formulation of the question

As noted, the position of the Sun in the sky varies in each area on the Earth's surface depending on the seasons and the time of the day, regardless of geographical location, with the exception of areas around the equator. (Figures 1-3). As a result, the energy of the sunray falling on any area varies in each season. In order to get the maximum energy from the rays falling on the solar panels, the rays must always fall on the surface of the panels at an angle of 90^0.

Figure 4 [2] shows a scheme of horizontal S_1 and sunray falling on the surface S_2 perpendicular to the direction of sun rays. As shown on the diagram, the intensity of sun rays falling on both surfaces is the same.

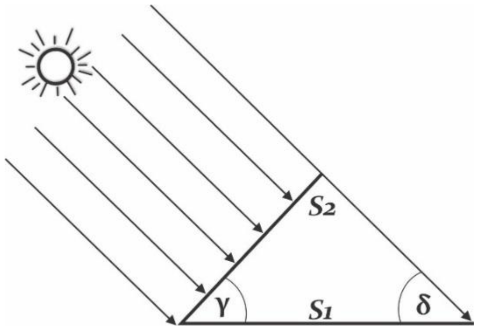

Figure 4 – Irradiance on a horizontal area S_1 and area S_2 perpendicular to the sunlight [2]

Assuming $E_1S_1 = E_2S_2$ to determine the value of radiant energy falling on surfaces [2], since $S_2 = S_1cos\gamma = S_1sin\delta$.

$E_2 = E_1 / sin\delta \geq E_1$ is obtained.

Here E_1 is the energy of the beam falling on the horizontal surface, and E_2 is the energy falling on the surface perpendicular to the rays.

As can be seen, the energy of the sunray falling on a perpendicular surface is greater than the energy of the sunray falling on a horizontal surface. In order to prove this, the above-written formula can be expressed as $E_1 = E_2cos\gamma$ [2], the value of sunray energy falling on the surface S_1 will increase significantly as the angle γ between the surfaces S_2 and S_1 decreases (γ = 5^0, $cos\gamma$ = 0,9962, γ = 10^0, $cos\gamma$= 0,9848, γ = 15^0, $cos\gamma$ = 0,9659, γ = 20^0, $cos\gamma$= 0,9397). This fact must be taken into account in the operation of systems that generate energy with solar panels. Surface orientation increases the energy received. This is especially relevant when the beams have a small angle of sunrays falling and high latitude.

Therefore, it is necessary to constantly change the position of the solar panels depending on the position of the Sun in the sky and to ensure that the sun's rays always fall on the surface of the panels at an angle of 90˚.

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Experimental part

The proposed device allows for achieving this goal. The specific feature of this device that distinguishes it from other existing devices is that, depending on the current value (change) of energy on the surface of solar panels, the position of the panels changes around the 1st horizontal axis and they are always oriented towards the Sun's position in the sky. Furthermore, this goal is achieved by slightly rotating around the 2nd horizontal axis perpendicular to the 1st horizontal axis so that the sun rays fall onto surface at 90^0angle.

The device consists of a block of solar panels (1), a block that changes its position around the 1st horizontal axis (2), a block that rotates its position around the 2nd horizontal axis perpendicular to the 1st horizontal axis (3), a converter which is converting electricity from solar energy(converter) (4), electrical energy parameters measuring block (5), power measuring block (11), memory block (12) and comparison block (13), control signal forming blocks (6 and 7), controllers (8 and 9) and a block (10) that transmits electricity to the network (Figure 5) [8].

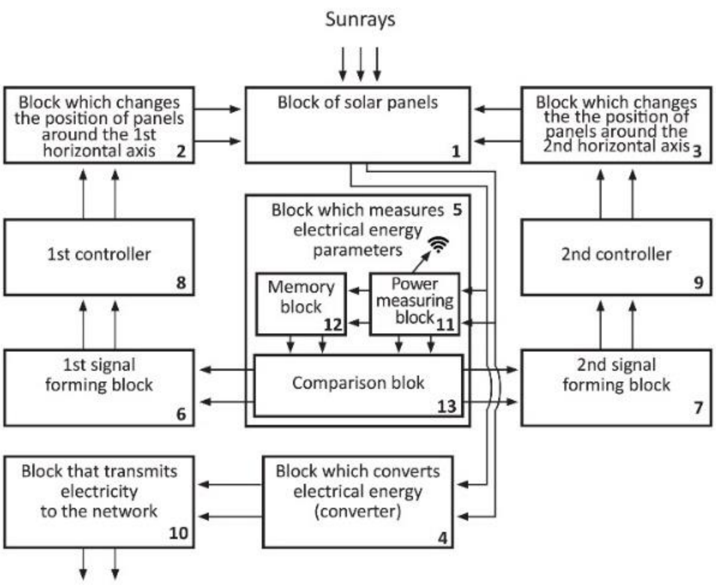

Figure 5 – Block diagram of the device [8]

The device works as follows. In order to get the maximum energy from the Sun in any area, the solar panel block of the device (1) is placed and activated according to the position of the Sun in the sky. The parameters of the electrical energy obtained from the conversion of the number of sunrays are constantly measured through the block (5) and the value

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of the maximum energy corresponding to the time of noon is stored in the memory block (12). As the Sun changes position in the sky, the decrease in energy is recorded by the power measuring block (11), the current energy value is compared with the maximum value stored in memory and proportional signals are transmitted to the inputs of blocks (6) and (7). The signals of blocks (6) and (7) generate appropriate control signals by the controllers (8 and 9) to change panel block positions (1). These signals are transmitting respectively panel positions to blocks (2) and (3), which are changing around the 1st and perpendicularly located 2nd horizontal axes. Blocks (2) and (3) change the position of the panel block respectively both around the 1st horizontal axis (according to the changed position of the Sun) and around the 2nd horizontal axis (so that the sunray falls on 90^0angle).

The need to change the position of the solar panels around the 2nd horizontal axis means to ensure that their surface is directed at right angles to the sunray in different seasons and places.

Thus, maximum efficiency in energy conversion is achieved due to the fact that the amount of sunray constantly falls on the surface of the panels at right angles during the day.

This approach makes it possible to achieve high efficiency in the operation of energy converters, taking into account their geographical location, seasonal changes, as well as time of day.

This is achieved by mechanically acting on the supporting structures on which the solar panels are located, moving them in one direction or another under conditions of reduced energy conversion.

In practice, it is possible to transmit the current values of power at the outputs of the unit, which measures the power of solar panels, directly to the center of the station via a Wi-Fi transmitter and thus record the amount of energy produced during the day.

A schematic view of a sample of the device consisting of 20 solar panels is shown in Figure 6 and the working algorithm is shown in Figure 7.

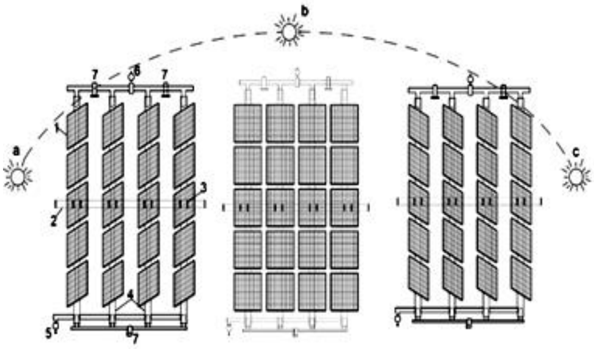

Figure 6 – Position of solar panels of the device in the morning (a), noon (b), and evening (c) [8]

The solar panels (1) are placed on the 1st horizontal axis (4) resting on the pads (3) on the fixed supports (2). The supports (2) also act as a second horizontal axis perpendicular to the 1st axis, which can move up and down around the panels. The panels have the ability to move (rotate) around the 1st axis from left to right and vice versa. This is due to the signals coming from block (5), which changes the position of the panels around the 1st horizontal axis. The position of the panels changes up and down around the 2nd horizontal axis due to the signals received from the block (6).

Blocks (5) and (6), which change the position of the panels around the 1st and 2nd horizontal axes, change the position of the panels in proportion to the value of the signals received from the controllers (8 and 9) included in the device (see Figure 5).

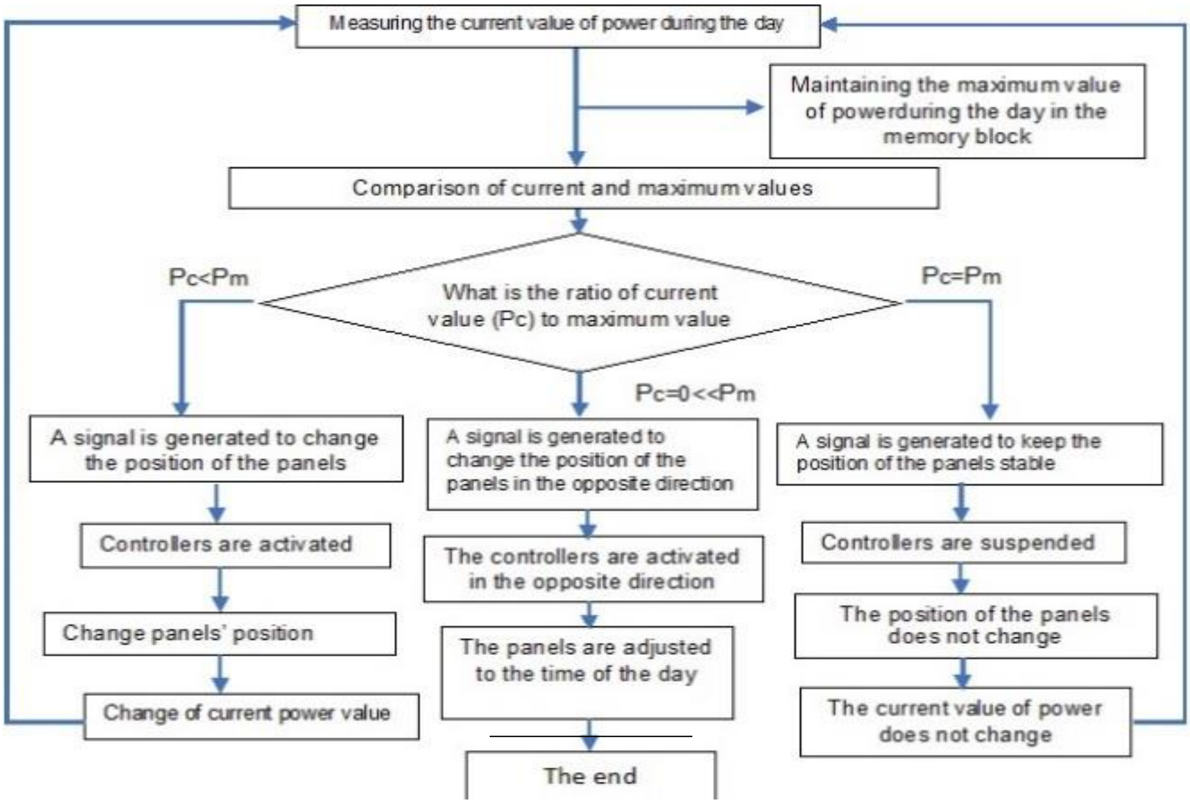

Figure 7 – Algorithm for managing the position of solar panels during the day [8]

These signals are formed on the basis of the difference between the signals obtained from the comparison of the maximum value of electricity received from the panels during the day with the current value.

Thus, as a result of changes in the current value of the energy received, the panels, which are placed at approximately right angles to the rising Sun in the morning, rotate and change their position to 900 near sunset time. At the same time, because of the signal from block (6), a slight change in the position of the panels around the 2nd axis (Figure 8.) ensures that the sunray is falling on the surface of the panels at an angle of 900 during the day. The panels are reset at midnight.

The solar panels (1) are placed on the 1st horizontal axis (4) resting on the pads (3) on the fixed supports (2). The supports (2) also act as a second horizontal axis perpendicular to the 1st axis, which can move up and down around the panels.

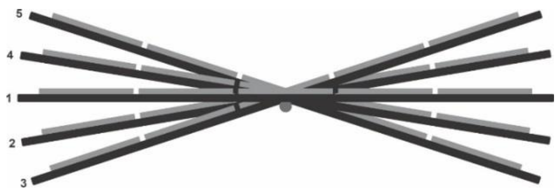

Figure 8 – Diagram of the change of position of the panels around the 2nd horizontal axis (side view) [8] *(1-position for June, 2, 3, 4, 5 – positions for other seasons)*

The panels have the ability to move (rotate) around the 1st axis from left to right and vice versa. This is due to the signals coming from the block (5), which changes the position of the panels around the 1st horizontal axis. The position of the panels changes up and down around the 2nd horizontal axis due to the signals received from the block (6). Blocks (5) and (6), which change the position of the panels around the 1st and 2nd horizontal axes, change the position of the panels in proportion to the value of the signals received from the controllers (8 and 9) included in the device (see Figure 5). These signals are formed on the basis of the difference of the signals obtained from the comparison of the maximum value of electricity received from the panels during the day with the current value. Thus, as a result of changes in the current value of the energy received, the panels, which are placed at approximately right angles to the rising Sun in the morning, rotate and change their position to 90^0 near to sunset time. At the same time, because of the signal from the block (6), a slight change in the position of the panels around the 2nd axis (Figure 8.) ensures that the sunray is falling on the surface of the panels at an angle of 90^0 during the day. The panels are reset at midnight.

The proposed device is essentially an automatic positioning system of solar panels (APSSP). The main distinguishing feature is that despite being iconic, both axes are located in the panel plane carrying control out in the function of power. The basic circuit consists of a power circuit that reflects the energy conversion (Figure 9) and a control circuit of the automatic positioning system (Figure 10). Regarding the software, the power circuit consists only of hardware and the control system consists of hardware and software.

The power circuit has a relatively simple and traditional structure. The composition of the equipment is shown in the figure below. The control circuit is based on the Arduino controller. Two TB6600 drivers were used to connect the execution motors (step motors are shown as an example in Figure 10). The performance of both the Ardunio and the TB6600 driver is the same as in the industrial models of these devices. Taking into account that the composition of the hardware is determined by the working algorithms of the software, it is better to start the explanation of the scheme with the software part.

Figure 9 – Power circuit of APSSP İnverter: for single phase-network: MUST EP3000 (12-14/220 V, 1-6 kVt); GW15K-DT (26 kVt and higher) GP-controller-solar panel controllers: (MPPT-controller): PC1600F; series 45/60/80A (MPPT)

The control program of the dual APSSP must perform the positioning in the power function. In this case, the issue of measuring or determining the current value of energy conversion capacity must be resolved.

Any power meter is installed in the DC circuit up to the inverter and the device measures the current value of power *P*. As the coefficient of efficiency of solar panels depends on the angle of falling sunbeams to the surface [9] and the changing angle of sunlight relative to normal direction is expressed by its sinus and cosines, the change in the current value of power relative to the maximum value should be expressed as follows:

$$P = P\max \sin\alpha \pm P\max \cos\beta. \quad (1)$$

Reduction of power relative to the maximum value:

$$\Delta P = P\max - (P\max \sin\alpha \pm P\max \cos\beta), \quad (2)$$

$$\Delta P = P\max (1 - (\sin\alpha \pm \cos\beta). \quad (3)$$

As can be seen, it is not known which part of the current value of the power determined by a measuring device decreases whether under the influence of the angle α or β. However, since the annual and daily velocities and directions of the Sun relative to the Earth is known, and it is possible to implement expression (3) with software. In this sense, the management of the power function should be based on the principle of program management. It is known from astronomical knowledge that the annual speed of the Sun relative to the Earth (in β coordinates) is 0.986 degrees/day or 0.041 degrees/hour, and the speed of daily movement (in α coordinates) is 15 degrees/hour or 0.25 degrees/minute.

Thus, for certain time intervals, it is possible to calculate the inclination values of the sun's rays relative to the norm drawn on the panel surface and enter them into the memory block shown in Figure 8. Assume that the maximum power inclination for the control task should not exceed 1%. For this purpose, the inclination angle of the sun's rays in both coordinates should be spaced over time so that the decrease in power relative to the maximum value does not exceed 1%. The following table (Table 1) shows the coordinates for a 15% annual movement and a 1% decrease in relative power during 1 hour of daily movement.

As can be seen, a 1% decrease in relative power occurs when the sun's rays are tilted by 0.6 degrees, which corresponds to a time interval of 2 minutes 24 seconds at the α coordinate, and 14 hours and 24 minutes at the β coordinate.

In Figure 10 step motors are used as an example, but DC motors can also be used for this purpose. Although step motors are relatively inexpensive, they do not have coordinated feedback lines. However, the developed control algorithms should be slightly modified while taking into account the practical operating conditions.

Thus, given the lack of energy conversion from sunset to dawn the next day and the fact that the annual speed of the Sun is many times smaller than the daily speed, it is more expedient to compile the algorithms as follows: In accordance with the conditions of the geographical location of the device, the time of daily dawn and sunset for a period of one year are recorded and saved;

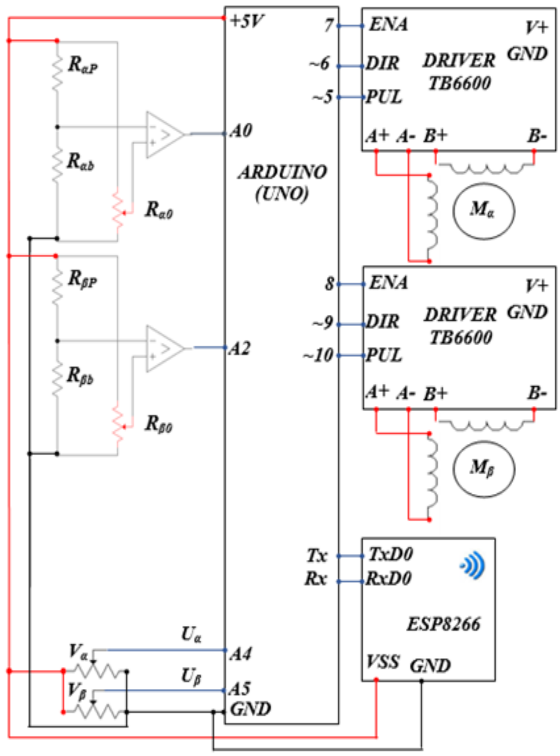

Figure 10 – APSSP management circuit $R_{\alpha P}$is a resistive potentiometer that provides a power-voltage matching resistor, a voltage divider resistor, and a comparator operating at a relative power reduction of 1%, respectively, $R_{\alpha b}$ & $R_{\alpha 0}$- *α*-coordinates; $R_{\beta P}$, $R_{\beta b}$&R_{b0} – *β* are similar elements in β coordinate; $V_\alpha V_\beta$ - rotation angle transmitters; M_α M_β are *α* and*β* coordinate actuators.

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Table 1 – The annual inclination of the sun, Daily inclination of the sun, and Relative change of power

№	Annual inclination of the sun		Daily inclination of the sun		Relative change of power			
	daily	hour	inclination (in degrees)	hour	minute	inclination (in degrees)	on the coordinate β	on the coordinate *α*
1	0	0	0,00	0		0		
2	0,6	14,4	0,59	0,04	2,4	0,6	1,05%	1,03%
3	1,2	28,8	1,18	0,08	4,8	1,2	2,09%	2,06%
4	1,8	43,2	1,78	0,12	7,2	1,8	3,14%	3,10%
5	2,4	57,6	2,37	0,16	9,6	2,4	4,19%	4,13%
6	3	72	2,96	0,2	12	3	5,23%	5,16%
7	3,6	86,4	3,55	0,24	14,4	3,6	6,28%	6,19%
8	4,2	100,8	4,14	0,28	16,8	4,2	7,32%	7,22%
9	4,8	115,2	4,73	0,32	19,2	4,8	8,36%	8,25%
10	5,4	129,6	5,33	0,36	21,6	5,4	9,41%	9,28%
11	6	144	5,92	0,4	24	6	10,45%	10,30%
12	6,6	158,4	6,51	0,44	26,4	6,6	11,49%	11,33%
13	7,2	172,8	7,10	0,48	28,8	7,2	12,53%	12,36%
14	7,8	187,2	7,69	0,52	31,2	7,8	13,56%	13,38%
15	8,4	201,6	8,28	0,56	33,6	8,4	14,60%	14,40%
16	9	216	8,88	0,6	36	9	15,64%	15,42%
17	9,6	230,4	9,47	0,64	38,4	9,6	16,67%	16,44%
18	10,2	244,8	10,06	0,68	40,8	10,2	17,70%	17,46%
19	10,8	259,2	10,65	0,72	43,2	10,8	18,73%	18,48%
20	11,4	273,6	11,24	0,76	45,6	11,4	19,76%	19,49%
21	12	288	11,84	0,8	48	12	20,78%	20,50%
22	12,6	302,4	12,43	0,84	50,4	12,6	21,80%	21,51%
23	13,2	316,8	13,02	0,88	52,8	13,2	22,82%	22,52%
24	13,8	331,2	13,61	0,92	55,2	13,8	23,84%	23,52%
25	14,4	345,6	14,20	0,96	57,6	14,4	24,86%	24,52%
26	15	360	14,79	1	60	15	25,87%	25,52%

The command "Start" is issued immediately at dawn; The "Start" command connects the control and power circuits to the power supply, and forms the "Ready" command; The “Ready” command generates task signals at α and β coordinates so that the panels are oriented in the normal direction towards the sun's rays; On the basis of the formed task signals, the panels are automatically positioned perpendicular to the sun's rays by means of α and β coordinate transfers; The deviation from the maximum value of the power on the α coordinate is determined by the time interval every 2 minutes and 24 seconds; The control signal is formed according to the value of inclination relative to the maximum power; 0.6degree positioning is performed in the direction of the diurnal motion of the Sun at the coordinate α; From the moment of completion of the operations specified in paragraph 5, after the expiration of 14 hours and 24 minutes, the deviation from the maximum value of power in the β coordinate is determined; The control signal is formed in accordance with the value of the inclination relative to the maximum power on the coordinate β; 0.6degree positioning is performed in the direction of the annual motion of the Sun at the coordinate β; According to the moment of sunset, the "Stop" command is formed, the panels are brought to the initial position according to the moment of dawn, and the control and power circuits are turned off; Paragraphs 2-12 are repeated periodically, for a specified period. As for the procedure for connecting the functional block diagram shown in Figure 8 to the Internet via Wi-Fi, it is necessary to specify the hardware required for this purpose. In our opinion, it is enough to create the hardware on the ESP8266 chip and -USB ~ UART adapter.

Thus, the ESP8266, as a modem, while having the function of a Wi-Fi emitter, has considerable practical experience in its use with Arduino. The USB ~ UART adapter is for creating software by connecting the ESP8266 modem directly to a computer or any laptop (USB is not shown in Figure 10). ESP8266 software is written in C ++.

The protocol for connecting the Arduino module to the Wi-Fi module consists of steps that can be considered quite standard: Connect the Arduino module to the power supply and wait for the "Arduino-Uno-WiFi-xxxxxx" (xxxxxx-module identifier) network to be reflected; Connect to this network from any Internet browser with IP address 192.168.240.1; Configure the module in the web interface while entering the Network SSID item and press the CHANGE button to reach the initial network settings of the Arduino module; Connect to a Wi-Fi network; Access Arduino Uno Wi-Fi network from any computer, laptop, or smartphone with a valid IP address; Using the SWITCH TO STA MODE button, change the network AP + STA mode to STA mode.

In practice, it is possible to develop a program by analyzing the indicators that reflect the management of the panels performance as a result of a one-year operation of the device located in any particular region and area in subsequent years for each season or month. It is also planned to create options to control the position of the panel units manually for the start-up preparation, maintenance, and repair of the unit.

From the structural point of view, the need to place such a set of panels at a certain height above the ground, unlike stationary structures, requires that they be mounted on solid supports and protected from external influences, such as wind erosion (restrictive supports (7) (Fig.6)).The distance between the first horizontal axes around which the panels rotate during the day is chosen so that the panels closest to the falling sunray (in the foreground) do not cast shadows on the surface of the panels after them, either when the sun rises in the morning or sets in the evening [10]. The solar panel block is built as a telescopic system based on the modular principle, which means that the number of panels in each row determines the number of modules. As the number of panels in each row increases, their angle of displacement around the second horizontal axis will also increase. In this case, it will be necessary to place the whole structure at a higher level than the Earth's surface.

But the infinite increase in the number of modules will lead to an increase in the size and weight of the overall structure and will complicate the operation of the device. In such cases, it is more appropriate to operate several parallel devices. In this case, all of them will operate and be managed on the basis of a single algorithm.

During the application of the device, the power supply of all its units, including the transmissions that change the position of the panels, is carried out at the expense of electricity directly from solar panels, which makes the operation of the device more efficient.

The parts of the solar panels placed in stationary positions close to the ground surface have different effects on the operation of the panels due to the fact that they are warming up quicker than the above parts. This shortcoming is completely eliminated in the proposed device so that the surface temperature of the panels will be consistent same everywhere.

Conclusion

In order to increase the energy performance of solar panels, the theoretical basis and the principle of construction of the device are explained, which allows changing their position around two horizontal axes perpendicular to each other depending on the value of energy obtained directly from the panels. In the operation of the device, the panels are always directed at right angles to the falling sunray amount, thus allowing to get the maximum possible energy from the panels during a bright day, regardless of the geographical location and season of the year.

Conflict of Interests

The authors declare there is no conflict of interests related to the publication of this article.

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