Microcontroller-based electromechanical drive

K V Selivanov*, I A Vasiliev and E S Lyuminarskaja

Department of electrical engineering and industrial electronics, Bauman Moscow State Technical University, 105005, Moscow, Vtoraya Baumanskaya street, 5, build. 1, Russian Federation.

* Selivanov_kv@mail.ru

Abstract. This paper covers design and implementation of automated electromechanical drives for solar panels. It substantiates the need for using these devices when ensuring highly efficient generation of electricity from renewable energy sources (RES) is required and when human participation in the deployment of the device is impossible. The paper also considers the possibilities of increasing the efficiency of mobile solar power stations due to their automatic positioning during deployment and tracking the motion of the Sun in the sky through automatic control by the microcontroller-based electric drive directed by the incoming signals of the maximum irradiance tracking. The results of experimental tests of the developed microcontroller-based electromechanical drive are presented.

The geographical spread of the solar panels (SP) use and the expansion of their areas of application make improving their operation and increasing performance an up-to-date task [1,2,3,4].

Among various classes of SP, there is a separate class of panels that are part of mobile power stations, which often change their geographic location and require frequent deployment and dismounting. They are used to provide power to mobile working groups operating in isolation from the centralized power supply lines and autonomous power supply centers. Such groups include exploration expeditions, military field camps, film crews, loggers, gold prospectors, etc [3,5,6,7,8].

The main problem of operating these mobile power stations is deployment and positioning of the SP that ensures their maximum efficiency. Currently, in most cases, the mounting and orientation of solar battery panels (SBP) is done manually. Manual mounting and positioning of SP is labor-intensive and does not provide maximum efficiency of electricity generation due to impossibility of reorientation of the SP during the day following the sun movement and significant positioning errors arising from the incorrect selection of the azimuth angle and inclination of the solar battery. These factors significantly impair the SP performance. In some particular cases, it is necessary to automatically position a SP without an operator’s participation. For example, in case of automatic sensing of areas by weather balloons dropped from an aircraft, an automatic positioning of the SP enabling maximum solar light exposure could significantly increase the efficiency of power generation.

This article is devoted to the analysis of possible solutions and the development of an automated microcontroller-based electromechanical drive for tracking the sun.
As mentioned earlier, to ensure maximum efficiency in SP power supply, the panels should be installed at an optimum angle to the incident sunlight. The direction of the Sun's rays in relation to the Earth's surface changes during the year due to the change in the incidence angle (declination) from 38 degrees at noon in winter to 86 degrees at noon in summer (figure 1).

Moreover, during the day, the sun moves across the sky, thereby changing the sunlight incidence angle relative to the solar battery. During the day, the sun moves about 130 degrees in azimuth.

![Figure 1. The change in the incidence (declination) angle of the sunlight.](image)

To compensate for the movement of the sun and keep the SP oriented at 90 degrees relative to the incident rays, it is necessary to develop a device that will position the SP in two planes — horizontal and vertical [9]. To achieve maximum performance, the SP should be at an angle that tends to 90 degrees relative to the incident sunlight (figure 2).

Controlling the vertical angle position of the SP will compensate for the annual changes in the insolation angle of the sunlight. While the SP rotation around the vertical axis will compensate for the change in the position of the sun during the day.

![Figure 2. Changes in the sunlight incidence on the SP.](image)

At present, the SP electric drive control is carried out by a microprocessor on the basis of data binding to the geographical coordinates and the loaded calendar. The microprocessor, depending on the positioning data specified manually or through the satellite connection, uses the assigned positioning table and, depending on the date and time, rotates the SP to the given vertical and horizontal positions. The disadvantages of this method are:
- Possible coordination positioning errors.
- Lack of consideration of uneven terrain and initial positioning angle setting.
- The device continues functioning and performing positioning correction in the absence of energy generation (cloudiness, rain, etc.)

The solution proposed by the authors suffers from none of the above disadvantages. This solution is to increase the performance and reliability of the solar panel by locating it on an automated electromechanical drive controlled by a microprocessor that tracks the direction of maximum solar radiation [10].

The device, automatically orienting the solar panel towards the sun, includes a solar panel mounted on a turning mechanism, additionally contains four digital light sensors, a central control unit connected to the light sensors and stepper motors mounted on the base. The turning mechanism enables automatic rotation with two degrees of freedom.

Figure 3 shows a schematic representation of the device for automatic orientation of the solar panel in the direction of maximum radiation. Four digital light sensors (1) are mounted in the center of a panel (2), on which the solar panels (3) are also located. The panel (2) with solar panels (3) and four light sensors (1) is located on the turning mechanism (4) with two degrees of freedom, to which two stepper motors (5) are attached. The stepper motors (5) and the light sensors (1) are connected to the central control unit (6), which, together with the turning mechanism (4), is fixed on the base (7).

The device operates as follows: the sunlight falls on the digital light sensors (1), then each sensor sends a digital signal about the solar irradiance intensity to the central control unit (6). In the central control unit (6) the comparison of the received signals is performed and after identifying the most intensive one, corresponding adjustment of the position of the panel (2) with the solar panels (3) in the direction of maximum solar radiation is made. The solar panels (3), located on panel (2), supply all components of the device with generated electricity and can be connected to an external consumer. After determining the direction of maximum solar radiation, the central control device (6) sends control commands to the stepper motors (5) to actuate the turning mechanism (4) in order to orient the solar panels. The support of the entire device is the base (7). The correction of the solar panel position is made after a certain time interval defined by the algorithm embedded in the central control device (6).

Electrical diagram of the designed device is presented in figure 4.

![Diagram of the device](image-url)
The developed prototype is presented in figure 5. To improve the sunlight tracking, four light sensors were used (figure 6), represented by photoresistors which change their resistance depending on the illumination. The photoresistors are shown in Figure 6. Signals from photoresistors are received and processed by a microcontroller. As the microcontroller Arduino Uno was used (figure 7).

The microcontroller, after receiving and processing the signals from the light sensors, sends control signals to two stepper motors, which position the SBP in the direction of minimizing the difference in
the photoresistors signals, thus turning the SBP at an angle tending to 90 degrees to the sunlight direction.

The effectiveness of the device prototype was tested on September 30, 2018 on a sunny day in the Moscow region, Zhostovo village. During daylight hours, from 7:47 to 16:36, the output energy from two solar panels was accumulated. The first solar panel was classic (stationary), installed with a south orientation and a slope of 40 degrees. The second solar panel of the same capacity was mounted on the developed device (the solar tracker) and changed its position during the day towards the maximum irradiation. The obtained data on the generation of electric current by the panels are shown as time plots in figure 8.

Figure 8. Comparison of the accumulated power of the classic SP and the SP with a microcontroller-based solar tracker.

Short-term dips in the solar panels power generation caused by the sun obscuration by clouds are not shown on the plots due to their transience, similar effect on both solar panels and the vanishingly small impact on the total amount of the generated electricity for each of the solar cells. In addition, for the purity of the experiment, the solar tracker was powered from an independent power source and did not in any way affect the total amount of generated electricity of the second SP.

The measurements showed an increase in performance of the second SP, installed on the tracker by 22-27% relative to the first (stationary). It is necessary to mention that the stationary battery was installed at the most effective vertical angle for September; in practice, stationary solar panels are installed at an average angle, which reduces the difference in energy generation during the winter and summer periods, but thereby reduces the maximum achievable effect. That is, in practice, the performance of a conventional stationary solar panel is even lower than in the experiment, which will further increase the effect from the application of the proposed device.

We should also note that the ability of the solar tracker to orient the solar panel vertically and horizontally in the direction of maximum irradiation allows compensating for possible errors during its installation and influence of uneven terrain on which the installation takes place. The device can actually be put in any initial position, the solar panel will automatically orient in the direction of maximum solar radiation, and in case of a long period of sunlight absence the microcontroller program
forces the panel to rotate for 360 degrees until the photoresistors detect the radiation. Technological novelty of the proposed device is confirmed by the Russian Federation patent for utility model No. 180765 “The device for automatic orientation of the solar panel in the direction of radiation”.

The obtained results verified the effectiveness of the proposed automatic electromechanical drive for microcontroller-based tracking device in increasing the SP generated energy amount due to their automatic positioning relative to the sunlight at an optimum angle. Using electric drives with automatic control by a microcontroller based on photoresistors feedback is very promising and is one of the first steps in the direction of dynamic positioning and automation in solar panels technology (solar power industry).

This solution can be effective not only for SP that do not change their geographical position during operation, but also for mobile stations. For example, for a geological expedition it is possible to generate electricity by solar batteries underway. The efficiency of the SP is ensured by automatic tracking of the radiation direction and constant adjustment of the solar battery position in a dynamic mode. The proposed device can also be effective in the case of automated remote installation of solar panels. After a module lands, the automatic electromechanical drive for microcontroller-based tracking device will orient the solar panel towards the sun, regardless of its initial position. At the same time, it will guarantee the effective power supply of the object after its remote installation.

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