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Calculation of Dynamic System of Solar Photo Electric Batteries

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ABSTRACT

The study presents the results of the calculation of the dynamic (auto-rotation) system of solar photovoltaic batteries, which shows that the power consumed by the auto-turning device depends on the size, mass and frequency of rotation of the device.

KEYWORDS: *Electricity, renewable energy sources, atmospheric mass, total current, photoelectric battery, two-axis tracker, photoelectric station, mechanical power, angular velocity, kinetic energy*

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1. INTRODUCTION

It is known that the consumption of energy resources is a decisive factor in the sustainable development of any country. Because a certain amount of energy is consumed to produce each type of product, that is, the unit cost of each unit of product is directly related to energy consumption [1-4].

Due to global economic development, by 2030 the demand for electricity will increase by 5% compared to the beginning of the century, and the demand for this will be 23.27 billion tons of conventional fuel [2,3].

39.1% of the world's electricity is generated by burning coal, 17.5% by burning natural gas, 16.9% by nuclear energy, 17.1% by hydropower and 7.9% by burning oil products [2-7].

As a result of the use of natural fuel and energy resources, the world annually emits 200 million tons of electricity. tons of solid particles, 200 mln. tons of sulfur dioxide, 700 mln. tons of carbon monoxide and 150 mln. tons of nitrogen oxides are extracted. As a result, various climate changes occur in nature and lead to severe air pollution [5].

The analysis of the above shows that the current global population growth and the growing demand for energy, the rapid development of science and technology, will lead to socio-economic, environmental and energy problems. This, in turn, will pave the way for more rapid development of renewable energy in the world, especially in our country.

2. Method

Determination of the strength of the supporting structures of the device and their resistance to wind speed and other influences through calculations for engineers and technicians designing and operating dynamic (auto-turning) systems (trackers) of solar photovoltaic cells (FEB), and for maximum absorption of sunlight. it is important to know the orientation, evaluate the efficiency of the application of the tracker, analyze the power consumption and show its dependence on the device parameters.

Methods of calculation, simplification, evaluation of efficiency, comparison and analysis were used in the study.

3. Results of the research

It is the basis of renewable energy sources. Solar energy is calculated. The source of solar radiation (QN) is the Sun, which has a mass of about $2 \cdot 10^{30}$ kg, a radius of 695300 km, a temperature of about 6000^0C in the photosphere, and 40 million ^{0}C in its core. In a year, the Sun radiates $1{,}3 \cdot 10^{24}$ calories of energy into space.

99% of the solar radiation energy corresponds to a wavelength in the range of 0.1 ÷ 3 μm. The solar spectrum consists of three areas: ultraviolet (λ<0.38 μm), the visible part of the spectrum (0.38 μm < λ <0.78 μm), and infrared radiation (0.78 μm < λ <3 μm).

The effect of atmospheric parameters on the intensity of solar radiation reaching the Earth's surface is determined by the atmospheric mass (AM):

$$AM = \frac{p}{p_0} \cdot \frac{1}{Sin\alpha} \quad (1)$$

where p is the atmospheric pressure and p_0 is the normal atmospheric pressure (101,3kPa),

α is the angle of elevation of the Sun with respect to the horizon.

The flux density E of solar radiation on the Earth's surface is determined by the following formula:

$$E = \int_0^\infty E_{0\lambda} e^{-\tau_\lambda m} d\lambda = \int_0^\infty E_{0\lambda} e^{\frac{-\tau_\lambda h}{Sin\alpha}} d\lambda = \int_0^\infty E_{0\lambda} P^{\frac{1}{Sin\alpha}} d\lambda \quad (2)$$

where - τ_λ is the absorption coefficient in the atmosphere depending on the wavelength, - QN is the distance traveled in the atmosphere, h is the altitude of the atmosphere, $P = E_{h\lambda} / E_{0\lambda} = e^{-\tau_\lambda h}$ is the transparency coefficient describing atmospheric absorption.

Solar radiation falls on an arbitrarily oriented receiving device on the surface in the form of three different solar energy flows (Figure 1). At each moment of time (t) on the surface, the total current QN to the receiving field RS (t) is as follows [3].

$$R_\Sigma(t) = R_{пр}(t) + R_\partial(t) + R_{от}(t) \quad (3)$$

where, the directional solar energy flux is Rpr (t); diffuse or scattered by clouds, aerosols, dust particles in the atmosphere - Rd (t); The return of a portion of QN from the surface in the reflected state is Rot (t).

Solar radiation is converted into electricity when it hits photoelectric batteries installed in an automotive turning device on the ground.

Below, we consider the dependence of the power consumed by a solar photovoltaic cell (FEB) autotransformer (dynamic system) device on the device size, mass, and rotational frequency, as well as the efficiency of the device and the relevance of using this technology.

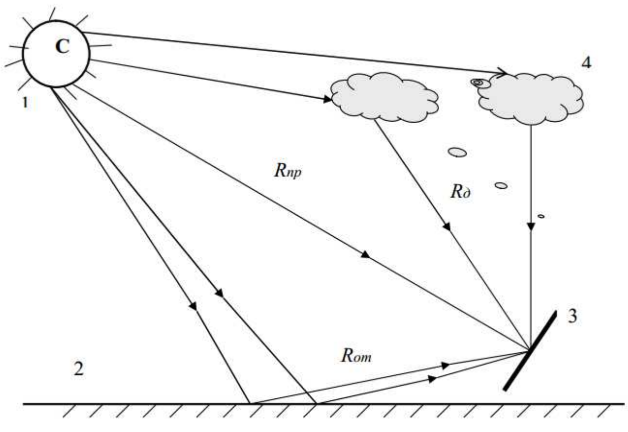

Figure 1. The main constituents of QN on the surface

1- Sun, 2- Earth's surface, 3- Receiving field, 4- Cloud, aerosol, dust.

Solar photovoltaic systems serve as an important part of the supporting structure for photovoltaic batteries (solar panels) [8-12]. It provides the necessary rigidity for the entire system and the correct slope angle for the solar panel. The combination of the base structure with the solar panel is required to be resistant to various wind speeds and other environmental influences.

FEBs are installed on base systems. The base system has two main views, namely static and dynamic. A characteristic feature of a static system is that the angle of inclination of the Sun-oriented modules cannot be changed. Logically, the solar modules should be maximally illuminated during daylight hours and oriented to the south.

The dynamic system is called a tracker in English. Its working process is very simple, the device is designed to monitor the Sun to the maximum, to increase the FIC. There are two types, the first is single-axle and the second is double-axle. A view of a photovoltaic station with a two-axis tracker is shown in Figure 2.

Figure 2. A solar photovoltaic station with a two-axis tracker.

A single-axis tracker changes its position relative to only one axis. Typically, such a tracker looks like a static structure, and when viewed carefully, this structure is equipped with an actuator, which changes the angle of inclination of the device. The actuator, in turn, consists of a motor-reducer and a stock. The stock attaches to the table and moves it up or down. A single-axis tracker changes its angle relative to the sun several times a year. This is managed through software that makes 2 to 20 changes per year.

A two-axis tracker is a complex engineering structure that can be oriented in two different planes. The difference between a two-axle tracker and a single-axis tracker is that it rotates the table at an unlimited 1800 angles, maximizing sunlight during the day from sunrise to sunset. It also has a safe mode in the horizontal position and is also resistant to strong winds. They automatically control the system for maximum sunlight reception. The efficiency of such a system is 30-40% higher than that of a static system. It is 15% higher than a single-base system.

The photovoltaic batteries (FEB) [13-15] auto-rotation system (hereinafter referred to as the solar tracker) serves to increase the power generation using them. According to the company that makes tracker models, the increase in power generation is up to 45% higher per day than the electricity produced without the use of solar trackers. The Solar Tracker also allows you to stabilize the value of electricity generated during a bright day [16-17].

The main disadvantages of solar trackers are:

1) consumption of electricity for special needs of the tracker;

2) the need for system maintenance.

In the catalogs of the company that manufactures tracker models, the value of electricity consumed by private devices alone is shown to be negligibly small, without specifying certain values of power consumption by transmission devices (stepper motors). The lack of this data makes it necessary to evaluate the effectiveness of using a solar tracker.

To do this, it will be necessary to conduct an analysis of the power consumption for the specific needs of the device, especially the transmission. Knowing that the rotation of the device depends on the mechanical force, it is also possible to determine the effect of the size (mass), mass and rotational frequency of the device on the required force. Let us consider a simplified model of a tracker to determine the mechanical force required for the rotation of a FEB with mass m, size h, l, f, and rotation frequency n around its axis. To simplify the calculations, we cannot take into account the effect of friction forces. A simplified drawing of the tracker is shown in Figure 3.

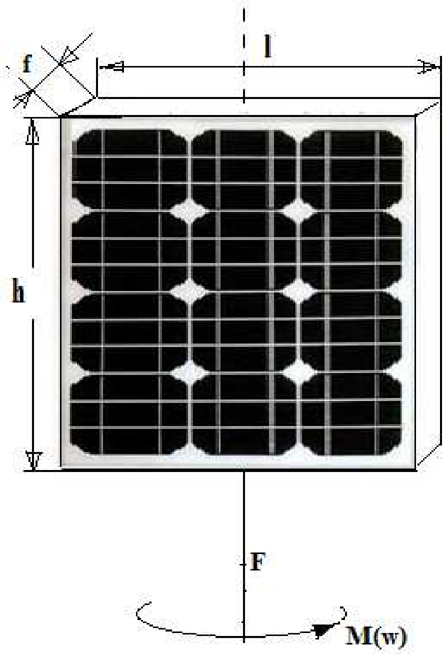

Figure 3. Simplified drawing of the tracker.

We use the following formula to determine the mechanical strength of an object:

$$N = \frac{E_{kin}}{\Delta t}, \ (4)$$

where N is the mechanical power, Wt; E_{kin} is the kinetic energy of the body after the end of the process, J; Δt is the process time, seconds.

We calculate the kinetic energy of an object using the following formula:

$$E_{kin} = \frac{j_c \omega^2}{2} \frac{\Delta\varphi}{2\pi}, \ (5)$$

where $j_c = \frac{m(l^2 + h^2)}{12}$ is the moment of inertia of the body about the axis passing through the center of mass of the body according to Steiner's theorem, kg • m2; ω —angular velocity, rad • s, $\Delta\varphi$ —change in angle of rotation, rad.

In that case, the formula for determining the kinetic energy will look like this:

$$E_{kin} = \frac{m(h^2 + l^2)\omega^2}{24} \frac{\Delta\varphi}{2\pi} \ (6)$$

Substituting (6) into (4) we obtain the mechanical force of the body:

$$N = \frac{m(h^2 + l^2)\omega^2 \Delta\varphi}{24 \cdot 2\pi\Delta t}, \ (7)$$

From the following expression for determining the angular velocity, we obtain the following by determining the value of $\Delta\varphi$

$$\omega = \frac{\Delta\varphi}{\Delta t}, \ (8)$$

$$\Delta\varphi = \omega\Delta t. \ (9)$$

Substituting (9) into (7), we obtain the formula for determining the force required for an object to rotate once around an axis passing through its center of mass:

$$N = \frac{m(h^2 + l^2)\omega^3}{24 \cdot 2\pi} \ (10)$$

According to formula (10), the results of the calculation of the force required for the body to rotate once around the axis passing through the center of mass are given in Table 1.

Table 1 Power calculation results.

$P_{НОМ}$, Wt	м.kg	h, m	l, m	n, circle/min	N, Wt
250	18	1,64	0,992	1	0,0005
250	18	1,64	0,992	10	0,503
500	36	1,64	1,984	1	0,0018
500	36	1,64	1,984	10	0,815
3000	108	3,28	5,952	1	0,038
3000	108	3,28	5,952	10	37,95

4. Conclusion

The results of the force calculation show that when the rotational speed of an object (FEB) is small, a small force is expended so that the body rotates once around an axis passing through the center of mass. As the mass (m) and dimensions (h, l) of the FEB increase, so does the force required for its rotation. The results of this study are of great importance for engineers and technicians who design and build dynamic (auto-turn) systems of solar photovoltaic batteries. In subsequent studies, it will be necessary to take into account the effect of frictional forces on mechanical supports and bearings, as well as FIC in different branches of the tracker.

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