CONTROL SYSTEM OF THE OPTIMAL PHOTOVOLTAIC MODULE ORIENTATION

M. Kitaeva [1], A. Yurchenko [1, 2], A. Okhorzina [1]
[1] National Research Tomsk Polytechnic University, Lenin Avenue 30, 634034, Tomsk
[2] Tomsk State University, Lenin Avenue 30, 634034, Tomsk
E-mail: kitaevam@tpu.ru

ABSTRACT: Designed control system of the optimal PV module orientation allowing not only to follow the maximum power of the solar radiation in the sky, but also to maximize received energy. There was designed a sample of the control system which consists a sensor, control unit and rotator. The sample of control system was held its full-scale tests during the year.

Keyword: Tracking, PV System

1 INTRODUCTION

The factor limiting the widespread using of solar energy is the cost of energy systems. Cost reducing of photovoltaic power generation systems is possible by cost decreasing of photovoltaic modules (PV) or increasing of efficiency. The simplest and most reasonable method is to improve efficiency of using tracking systems. The tracking system provides more uniform generation of electricity from sunrise to sunset. This is achieved with a constant PV surface orientation to the Sun, which ensures perpendicular falling sunlight on the PV surface.

The main features that determine the further development of photovoltaic in the world and Russia are:

- Environmentally friendly;
- Large stocks of raw materials (silicon);
- Photovoltaic module has high operational qualities: the long lifetime (~ 20 years), high reliability and automation.

2 METHODS DECREASE COSTS

Cost reduction of electricity production using the PV is possible in two ways: cost reduction the PV and increasing collection energy efficiency. The first method is implemented in the following ways:

- Reduction in the cost of production PV through creation of automatic production of PV;
- Cost reducing of solar silicon through replacing the single-crystal and polycrystalline silicon on multicrystalline silicon;
- Replacement of solar silicon to other materials (eg , gallium arsenide - aluminum arsenide) .

A second method to increase the effectiveness is achieved as follow:

- Using tandem systems, multilayer photo detectors heterojunctions, although this increases the cost of the power system;
- Application of the bilateral photoelectric converter, which leads to a slight increase in efficiency;
- Addition of various hubs, which, along with the increase in production capacity, significantly increase the temperature of the elements, which negatively affects the efficiency;
- Introduction of solar tracking system, which can significantly increase the efficiency of conversion of sunlight into electricity. [1]

3 THE EFFICIENCY OF THE SOLAR SYSTEM

The efficiency of the solar system within a month characterized by the ratio of the average received power to the value of the average incoming solar radiation.

$$E = \frac{Pss}{Sr}, \qquad (1)$$

Where
E - efficiency of the solar system;
Pss - the average received power;
Sr - average incoming solar radiation.

Control systems can increase worked out PV power, but their use leads to the cost of power rotary device. Thus, the resulting output - it is the difference collected and consumed power PV rotary device:

$$Pss = Ppv - Porient, \quad (2)$$

Where
P*pv* - average daily power PV elaborated;
*Porien*t - average daily power consumed rotary device;

For maximum power necessary to develop an effective method of system control. The technique works control system is to detect the position of "bright spots" in the sky and focus on PV "bright spot."

For performance of the first action developed photovoltaic sensor (PVS), characterized by analog high sensitivity, the minimum dependence of the output signal from the ambient temperature to determine a "rising", measuring the level of background radiation to determine the necessary orientation. A detailed description of the design and operating principle of the PVS are presented in [2] (fig.1).

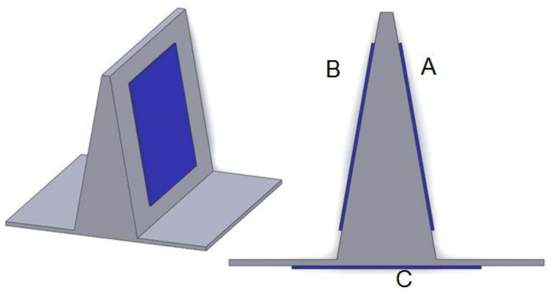

Figure 1: Photovoltaic sensor

For the effective implementation of the second action method is necessary to choose parameters such orientation that the resulting capacity, consequently, the efficiency of the solar system
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Power spent on orientation PV *Ppu* depends on the power consumption of the rotator and the time of continuous operation:

$$Porient = Ppu * t, \qquad (3)$$

where

Ppu - power consumption of the rotator;

t - time of continuous operation of the rotary device.

Power consumption of the swivel device will be maximized if the control system will operate continuously. To avoid this possible casual work rotator using the "sleep mode" control system. In this case, the power consumption of the rotary device will depend on the interval between the switching system (on which angle deviates sun from normal PV during this time), and the speed and the pitch of the rotator (the speed at which the rotator overcome the deflection angle of the sun from normal PV):

$$t = T/\omega, \qquad (4)$$

Where

T - interval between the switching system;

ω - the speed of the rotator.

The use of "sleep mode" control system reduces power PV worked out, so you need to calculate the time interval between the switching on to win power from the orientation exceeds the power expended in orienteering PV.

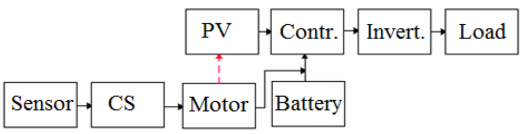
The parameters affecting the power consumption of the rotator are: the time interval between the switching system and move the rotator

4 CONTROL SYSTEM

Orientation to the Sun is possible using single-axis and dual-axis systems. The principle of operation is the constantly orientation perpendicularly to the surface PV of falling of sunlight. This increases the amount of solar radiation falling on the plane PV and quantity of produced energy. The aim of this method is to obtain the maximum amount of energy flux, improve the accuracy and reliability of PV.

Active systems have the greatest development. They have long time been used to orient the spacecraft Today they have got their spread on the ground. Closed-loop types of Sun tracking systems are based on feedback control principles. In these systems, a number of inputs are transferred to the controller from sensors which detect relevant parameters induced by the Sun, manipulated in the controller and then yield outputs (i.e. sensor-based).[2]

Typical scheme active system includes (fig. 2):



PV – photovoltaic module;

Contr. – controller;

Invert. – invertor;

CS – control system;

Figure 2: Typical scheme

The main problem is the formation of the pattern of the control signal from the sensor to the control system tracker.

The most urgent problem is to develop a sensor responsive to the changing position of the sun, with the necessary precision and optimum material costs

Closed-loop [2] tracking system has been developed. This system includes photovoltaic sensor, control device and motor. Photovoltaic sensor (PVS) is designed basing on the analysis of the sensors for tracking systems. The sensor allows excluding the effect of background radiation, to solve the problem of the system start-up in the morning. It is simple in application and not expensive. The dependence year power gain from tracking time step has been calculated, using mathematics model of PV system work.

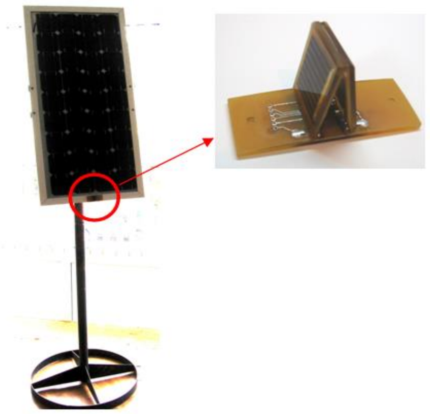


Figure 3 : Photovoltaic system with tracker

5 THE METHODOLOGY OF THE SYSTEM OF CONTROL OF MAXIMUM ILLUMINATION PV

For maximum output power of the PV is necessary to develop an effective algorithm of the rotator. To do this, consider the following factors:

1. First we need to determine whether the surface orientation of the PV, i.e. determine the level of illumination (as at night and in cloudy weather does not make sense to include the rotator).

2. To exclude cranking PV on 360˚ and, as a result of entanglement of wires need to install limit switches in the end positions PV signal from which would indicate the need to stop.

3. To reduce the energy consumption necessary to enter standby mode or turned off for a while.

4. To avoid short-term interference factors such as the flight of bird, cloud and shade short straight. Necessary before is using the command of rotating mechanism to carry out several measurements of the output current from the sensor elements at an interval.

Given the above, the program developed an algorithm.

It starts with the ability to determine whether to block orientation. The wire measuring and recording the signals of each sensor element at intervals of 10 seconds three times. In the first step we obtain the values of A1, B1 and C1, the following A2, B2 and C2, and the third, respectively, A3, B3 and C3, then, if the values obtained with the same element differ among themselves by more than 10%, the resulting entries are removed, and the measurement and recording are carried out again. This occurs three times. If three times failed to get values from a divergence of less than 10%, it indicates the Rain, in which the orientation is impossible, since It is changing the position of the bright spot at high speed. In this case, the branch instruction is fed into a "sleep mode" for 30 minutes.

If the difference between the three values from one element of less than 10%, the average values of the signals of each element is compared with a threshold signal corresponding to night. If at least one value exceeds the threshold value, then proceeds to block determining sunrise. Otherwise (that night), the system goes into standby mode for 30 minutes.

To determine the rising signal C is compared first with A, then B. If, in both cases it is, it indicates the occurrence of sunrise and controller unit gives the command to turn the PV eastward to the end position.

The next block is responsible for the orientation of the plane of the FM during the day. Mean values of the signals A and B of the sensor are compared. If one value is greater than the other by more than 1%, is commanded to rotate one step in the direction of more. This happens until the difference between A and B will not be less than 1%, indicating that the PV orientation to the brightest spot. The system then goes to sleep for 30 minutes.

Note: before each command rotation of the engine, is checked the corresponding limit switch. When you turn to the right - to check the right trailer, and left-left. Thus, the problem of entanglement and cranking ferromagnetic wires.

The described method of the system monitoring the position of the sun to determine the orientation of the need to solve the problem run the system in the morning, used to sleep mode to reduce consumption, and holding several measurement signals of the sensor elements with an interval of 10 seconds eliminates the interference of short-term factors.

6 THE EFFICIENCY OF PV ENERGY

Based on previous data, we calculated the efficiency of the solar module during the year. Efficiency was calculated as the ratio of the PV module average power generated during the day to coming in for a day of solar radiation on the surface of the PV module [2,3]. The results are shown in Fig. 4.

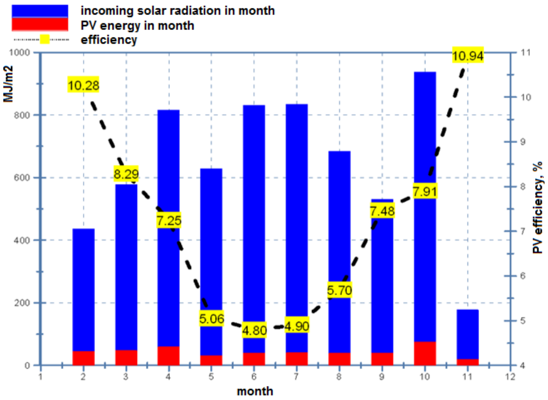


Figure 4: Effectiveness of PV module

Figure 6 shows that the effectiveness of PV module varies greatly in different months. The maximum value is achieved in the winter months; this is due to a high proportion of reflected light from the snow in the winter, as well as due to the low angle of declination of the sun, and light falls on the solar module throughout the day. In the summer months the efficiency a PV module is significantly reduced due to the fact that the sun in the morning and evening is the surface of a PV module due to high seasonal angle.

On average the efficiency is about 6%, which is about half the maximum possible efficiency for a used the PV module (η_{PV} = 13.8%, the efficiency is a parameter specified by the manufacturer in the passport on the basis of laboratory tests PV module). Efficiency can be increased by using more modern modules, tracking or combined systems.

7 SUMMARY

One of the effective ways to increase solar power collected by PV module is a solar tracker. Position of the maximum power of the solar radiation sometimes does not comply with the position of the Sun. Designed control system of the optimal PV module orientation allowing not only to follow the maximum power of the solar radiation in the sky, but also to maximize received energy. The most effective time interval between switching-on of the system was defined by mathematical modeling of PV module and solar tracker working. By using this interval energy obtained by PV module exceeds energy spent on orienteering. There was designed a sample of the control system which consists a sensor, control unit and rotator. Specially designed sensor which detects the position of the maximum solar radiation flux during the day, has minimum temperature dependence. The control unit includes a microcontroller. The algorithm of the microcontroller allows to determine the necessity of orientation and to solve the problem of system start-up in the morning. Power consumption reduces because of a sleep mode. Holding several measurement signals of the sensor at intervals eliminates interference short-term factors.

The sample of control system was held its full-scale tests during the year. The test results confirmed the fidelity calculations. During the tests it was found that the coefficient of conversion of solar energy into electrical energy by PV module, much lower PV module efficiency. The authors propose a new term "efficiency of using solar energy by PV module". This criterion allows to evaluate the efficiency of PV module in natural conditions as close to reality as possible.

8 REFERENCES

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