Photoelectric panel with equatorial mounting of drive

M S Kukhta [1]**, P Y Krauinsh**[1]**, D P Krauinsh**[1]**, A P Sokolov** [1]**, S B Mainy**[2]

[1] Tomsk Polytechnic University, 30, Lenina Av., Tomsk, 634050, Russia
[2] Tuvan State University, Lenina St., 36, Kyzyl, the Republic Tyva, Russia

E-mail: eukuh@mail.tomsknet.ru

Abstract. The relevance of the work is determined by the need to create effective models for sunny energy. The article considers a photoelectric panel equipped with a system for tracking the sun. Efficiency of the system is provided by equatorial mounting, which compensates for the rotation of the Earth by rotating the sunny panel in the plane of the celestial equator. The specificity of climatic and geographical conditions of Tomsk is estimated. The dynamics of power variations of photoelectric panels with equatorial mounting during seasonal fluctuations in Tomsk is calculated. A mobile photovoltaic panel with equatorial mounting of the drive has been developed. The methods of design strategy for placing photovoltaic panels in the architectural environment of the city are presented. Key words: sunny energy, photovoltaics, equatorial mounting, mechatronic model, wave reducer, electric drive.

1. Introduction

In the modern world, alternative renewable energy sources that use the light and heat of the Sun are widely used [1]. The sun is an environmentally friendly source of energy and does not produce greenhouse gases and has no toxic waste.

Photovoltaic panels are used to convert light; solar heat collectors are used to convert heat. Consumers of sunny energy in the first place are countries with a deficit of their own power resources, hard-to-reach regions, areas of natural disasters. Photovoltaic provides a stable level of electricity in the sunny countries of the equatorial belt and can be recommended as an additional, renewable, environmentally friendly energy resource for the northern latitudes of Russia. The irregularity of the solar flow and the specificity of the climate require the development of effective methods of technology and the design of photovoltaic panels.

The subject of the study of the article is the photoelectric mobile sunny panel. The purpose of the research is the development of technology and design of the photoelectric moving panel with equatorial mounting of the drive. The article considers design strategies for placing photovoltaic panels in an architectural environment.

2. Features of solar regimes in Tomsk

Tomsk coordinates are 56°29'54 " of northern latitude and 84°58'27 " of east longitude, the maximum angle of the Sun rising above the horizon in Tomsk in summer is 57, 00299°. The maximum angle of rise of the Sun in the winter is 10,00229°. The dynamics of the change in the mean value of total radiation, kWh / m^2 per day, depending on this latitude and the month of the year, is shown in Fig. 1. The arrival of solar radiation to the earth's surface depends on the transparency of the atmosphere, the number and shape of clouds, the formation of which is determined by synoptic conditions. The
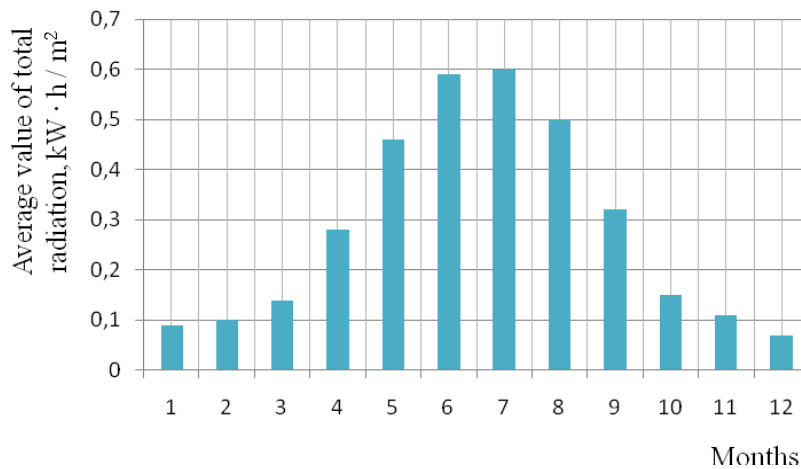
transmission ratio is 0.7 (data according to [2]).

Figure 1. Dynamics of changes of average values of full radiation.

Based on the research, it was noted that in general in Tomsk region a fairly stable radiation regime with minimal fluctuations is observed, both monthly and daily values of total radiation in March [3]. A feature of the radiation regime in Tomsk region is the shift in the maximum of the total daily radiation for June-July.
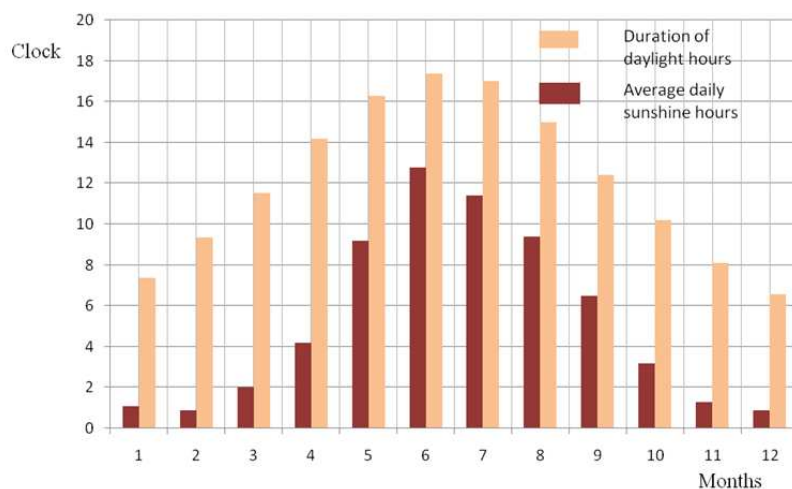

Figure 2. Illumination by the sun for Tomsk.

There is a complex dependence of the daily total solar radiation during the year, depending on the type of air masses, which reflects the features of the circulation of the atmosphere over the region [3].

The duration of daylight hours and the average daily amount of sunshine, during which direct sunlight reaches the Earth's surface, are shown in Fig. 2 (averaged weather data for the last three years). From these data it follows that the minimum duration of daylight hours is in December - January (6:56 - 7:36 h), and the maximum duration of daylight hours is from March to September (11:55 - 17:42 h).
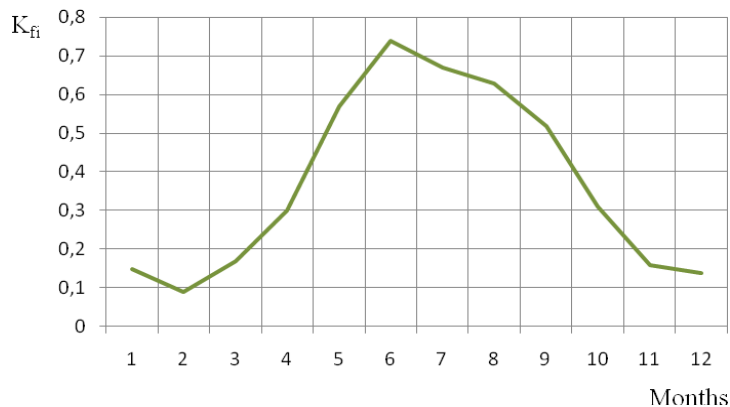
Figure 3. Changes of coefficient of actual insolation in Tomsk.

On the basis of data in Fig. 1 the change in the coefficient of actual insolation K_{fi} during the year in Tomsk is calculated (Figure 3), the minimum value of which is 0.09 in February, and the maximum value of 0.74 - for July (data for 2016)

3. Mobile photovoltaic panels: the current state of the problem

The efficiency of the photovoltaic panel is determined by its position relative to the sun. The actual power output of sunny panels and the magnitude of their charging current depend on the angle of incidence and density of sunlight, on which the state of the atmosphere affects (cloudiness, atmospheric precipitation, humidity and other climatic factors). There are mobile photovoltaic panels turning behind the Sun, and fixed photovoltaic panels.

Movable sunny panels are controlled by a special device that allows one to monitor the position of the sun and rotate the sunny panels so that their working surface is perpendicular to the sun's rays. This allows increasing the production of solar energy by 25 - 30%, ensuring maximum efficiency in the day and in the annual cycle. Two main types of rotary devices are known: monaxial (one drive rotates the sunny panels in the sun) and double-axis (two drives rotate the sunny panels in the sun). A single-axis rotary device does not allow automating the correction due to the seasonal change in the solar motion trajectory. A two-axis swivel requires increasing the energy consumption of the second axis (increases the cost of the drive). In the process of studying sunny panels in the United Arab Emirates, it was revealed that an autonomous photovoltaic system supported by a single-axis tracking system is technically and economically more efficient than a system with two-axis tracking technology [4].

In Algeria, the influence of the angle of inclination and orientation on the maximum power of the photovoltaic panel was studied and models of tracking the panel behind the solar trajectory are presented. Efficiency is ensured by maintaining the panel perpendicular to the sun's rays. Therefore, to determine the angle of the azimuth, the angle of inclination of the solar corners and the slope of the panel, the sun trajectory during the day is monitored every hour of the day using the Matlab software [5].

4. Photovoltaic panels in sunny, cloudy and cloudy days

The change in solar radiation on cloudy and clear days offers various algorithms for tracking the sun. The analysis of the sunny panel model conducted by Canadian researchers led to the conclusion that the solar tracking strategy at the zenith for cloudy or mostly cloudy days in the summer is not profitable [6].

The studies of Nelson and Gibson [7] revealed that dual-axis tracking improves the total capture of solar energy by a specified area of modules by 30-50% compared to fixed-slope modules. On sunny days, direct solar radiation is up to 90% of the total sunny energy, and the remaining 10% - from scattered sunny energy. However, during cloudy conditions, almost all solar radiation is diffuse radiation, isotopically distributed throughout the sky. This made it possible to improve the tracking

algorithm: in sunny and cloudy weather, use two-axis tracking, and on cloudy days to orient the panel horizontally, providing a solar capture of almost 50% compared to a two-axis tracking of the sun during the same period.

5. Equatorial panel mounting

Tomsk Polytechnic University has developed a sunny power plant with a movable photoelectric panel, the tracking system of which uses equatorial mounting. For equatorial mounting, the output axis of one of the drives of the rotation device of the photoelectric panel is oriented so that this axis is parallel to the earth's axis.

Equatorial mounting compensates for the rotation of the Earth by rotating the sunny panel in the plane of the celestial equator, if a mechanism is placed on this axis, which turns it one turn in 24 hours in the direction opposite to the rotation of the Earth. The sun in this case is always captured by the sunny panel. Equatorial mounting allows the use of only one servo drive (mechatronic azimuth module), which reduces the cost of the tracking system (the second drive is used for example only once a day to correct the position of the system for direct ascension and this drive can be greatly simplified).

Structurally in the control system of photovoltaic panels, a mechatronic module is allocated which controls the sunny panels in terms of elevation and azimuth
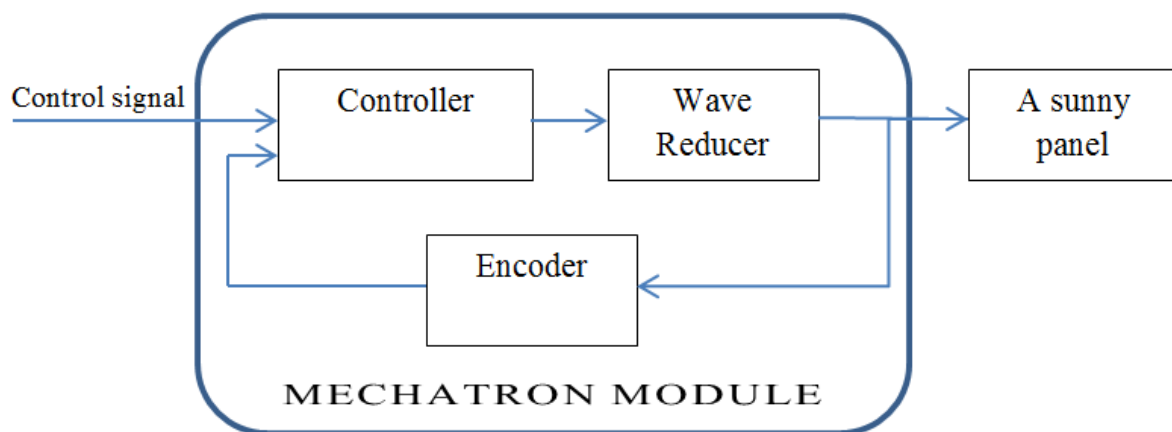

Figure 4. A block diagram of the mechatronic module of the sunny panel.

The mechatronic module provides the necessary positioning of the photovoltaic panel by signals from the absolute position sensor (for example, the encoder) and information about the position of the sun coming from the control unit. The electric power supply of the control system is carried out by an energy storage device, which is controlled by the power controller.

Figure 5. The sunny panel with the tracker system (development of Tomsk polytechnic university).

The photoelectric panel drive provides both automated and automatic control of the position of the sunny panels in terms of elevation and azimuth. With automatic control with the maximum level of generated electricity, it is necessary to have an expensive mechatronic module for each coordinate of rotation (azimuth and place). Mechatronic modules (Fig. 4) position the photovoltaic panels with high accuracy and thereby control the efficiency of electric energy generation, which allows obtaining a stable level of electrical energy [8, 9]. One of the important parts in the solar tracking system (mechatronic module) is a high-precision wave reducer controlled by the controller according to a given program and controlled by position - a feedback sensor (for example, an encoder). The wave reducer has significant gear ratios and small angular backlashes (fractions of angular minutes), high angular rigidity of the output link and a considerable resource. If the movable sunny panel is controlled so that its plane always remains perpendicular to the ray from the center of the solar disk, then the energy efficiency of such system will be maximized. The power produced by such movable sunny panel at the pole and at the equator is insignificant (up to 5%).

6. The design strategy of placing photovoltaic panels in an architectural environment

Photovoltaic panels can be included in the architectural environment in the following variants: as a building material for facing buildings (fixed photoelectric panels); as enclosing structures of buildings (mobile and fixed photoelectric panels); as an exterior design (movable and fixed photoelectric panels).

The development of a design strategy involves the creation of a harmonious design of a photovoltaic panel that ensures both energy efficiency and the requirements of technical aesthetics in the design of the urban environment [10]. The arrangement of panels as exterior and enclosing elements of architectural objects assumes their compositional connection with elements of the environment. The design strategy assumes a harmonious complementarity of the spatial design of the architectural object and technical solutions relating to the physical, mechanical, technological characteristics of the enclosing or exterior structures of photovoltaic panels. The design strategy for

moving panels has three options: collage (combining seemingly incompatible elements), integration (complementarity of elements), domination (positioning of the photovoltaic panel as the dominant of the architectural design). The most common is collage, especially in areas of spontaneous development. The other two (integration and domination) require additional funding from the customer. The costs are more than the more stringent urban norms and rules.

7. Conclusion

The dynamics of the annual change in the coefficient of actual insolation in Tomsk is presented, which allows us to rationally design sunny panels taking into account the specific climatic, synoptic, geographical, meteorological conditions. It is shown that the value of the actual insolation coefficient in Tomsk varies from 0.09 in February to 0.74 in July. Analysis of movable structures of photovoltaic panels showed that movable panels require a separate protected space that ensures the safety of their operation; assume the maintenance of complex mechatronics (in this example, ensuring the operation of the drive and the wave reducer); the reliability of the mobile sunny panel is 10 years. The energy efficiency of mobile photovoltaic panels increases with the use of the Sun tracking system, in which equatorial mounting is applied. In this case, only one servo drive is required. This reduces energy costs for the servo system and, accordingly, increases the energy efficiency of mobile photovoltaic panels. Low sunny panel power in winter for 56 ° north allows them to be used only for emergency lighting, and high in summer for additional domestic needs. The recommendations of the design strategy for ensuring the requirements of technical aesthetics and harmonization of the architectural environment have been worked out.

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