Calculation of the intensity of solar radiation

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Abstract: This paper of this work is the solar radiation of methods for calculating the intensity of solar radiation by the analytical method and the method of coefficients. At the stage of developing a feasibility study for a solar heating system project, the choice of a method for calculating the influx of solar radiation intensity is important. As a result of the calculations, the graphs of the dependences of the total inflow of the specific heat flux per 1 m2 during the year were obtained, calculated using various methods. The calculations showed that the amount of incoming heat calculated by various methods differs significantly.

1 INTRODUCTION

The solar power system seems to be very simple. As in most other power supply systems from autonomous sources, it has only 4 main components the photovoltaic panels themselves, batteries, a charge controller and an inverter that converts low-voltage direct current to a household standard of 220 V. However, all elements must be coordinated with each other. And if the components common to all such systems (inverter, batteries, wires) are considered on a separate page, then here I want to consider components specific to photovoltaic systems - photovoltaic panels (solar panels) and controllers for them. But, of course, first of all, the most important question is considered the choice of the power of solar panels or, which in real life, with its inevitable limitations in financial and material resources, is much more relevant - how to determine what kind of result can be expected from solar panels of one or another nominal power , that is, is the game worth the candle [1].

Unlike traditional energy sources, the operation of a photovoltaic battery depends on both climatic and technological factors. The whole set of factors that affect the operation of a photovoltaic battery can be divided into two groups:

1. Factors due to the design and manufacturing technology of the photovoltaic array and the photovoltaic installation, the angle of the photovoltaic array in relation to the horizon, the characteristics of the photovoltaic array, etc.
2. Climatic factors due to the impact of ambient solar radiation on the output energy characteristics of a photovoltaic battery. Such factors include solar radiation, air temperature, air dustiness, humidity, wind speed [2]. When designing a solar energy system, it is necessary to take into account the climatic features of the region where it is planned to use a photovoltaic battery. For this, full-scale tests of a photovoltaic battery were carried out with simultaneous monitoring of atmospheric parameters.

Determination of the possibilities of the Sun. The calculation of electricity needs for a particular mode of its use is considered on a separate page. Now we need to determine the possibilities of the Sun and, before starting to invest our money and our time in the creation of the system, solar radiation these possibilities with their needs. The basis for calculating expected energy production is data on the power of solar radiation, taking into account weather conditions. It is desirable that the data be for different angles of the panel, at least for vertical and horizontal orientation.

The most important issue is the choice of the angle of the panel. Bearing in mind the possibility of year-round use, an angle of 15° more than the geographical latitude should be preferred (in addition, the greater the slope, the less dust and snow will linger on the panel). For Moscow, this is 70°, since I have the opportunity to install a panel with a south orientation at such an inclination (deviation from the south direction by about 10 ° to the east is unprincipled).

By the way, if the winter use of solar panels is not expected, they may well be placed on a wall or roof slope oriented not to the south, but to the west or east, and in this case it is better to increase the slope of the panels along the solar radiation direction with the optimal direction for summer or in general, install the panels vertically, since in the morning and evening the Sun is close to the horizon.

2 Materials and Methods

The purpose of this work is the solar radiation of methods for calculating the intensity of solar radiation by the analytical method and the method of coefficients. Calculation of the intensity of solar radiation by the method of coefficients. The intensity of solar radiation, which enters the surface of any spatial position every hour of daylight hours $q_{day.1}$, is determined by the formula:

$$\gamma = \left|1 - \frac{\eta_1}{\eta_0}\right| \quad (1)$$

where $q_{day.1}$ is the intensity of solar radiation for each hour of daylight hours;

P_A is a coefficient that takes into account the azimuth of the SC placement. P_s is the SC position coefficient for direct solar radiation (Table 1. [3]).

If the NC is oriented to the south, then the coefficient PA =1.

Ps is the SC position coefficient for direct solar radiation (Table 1. [4]).

A photo power plant (Fig. 1) consists of solar modules, wind turbines, batteries, an inverter, a controller, and other devices. When energy sources (solar and wind power) are plentiful, the generated power, after meeting the load demand, will charge the battery. Table 1 shows a list of the main equipment [5].

Table 1. Shows a list of the main equipment. Determines the ratio of the intensity of direct solar radiation, which enters the plane of southern orientation, located at an angle β to the horizon, to the intensity of direct solar radiation, which enters a horizontal surface.

I_s^{sop} is the intensity of direct solar radiation that enters ahorizontal surface, W/m^2;

I_d^{sop} is the intensity of scattered solar radiation that enters a horizontal surface,P_d is the collector position factor for diffuse solar radiation.

Data on I_s^{sop} and I_{dsop} values for individual cities are given in the appendix. In the absence of data, you can use the approximate values of the hourly sums of direct and diffuse solar radiation according to the zoning map and weather data [6].

Calculation of solar radiation intensity analytically. In accordance with the methodology: The magnitude of the intensity of solar radiation q, W, incident on 1 m^2 of the inclined plane of the surface surface in each hour of daylight hours, under real conditions, is determined by the formula:

$$\eta = ff\frac{j_{sc}U_{oc}}{WS} \quad (2)$$

then (2) can be written as

$$\gamma = \left|1 - \frac{j_{sc,1}}{j_{sc,0}}\right|$$

where I_s and I_d are the specific heat flux, W/m2, of direct and diffuse solar radiation incident on a horizontal surface at latitude ϕ of a given area; these data are given in climate reference books;

β - is the angle between the considered plane and the horizontal surface (i.e., the inclination of the solar collector plane to the horizon);

δ - declination, i.e., the angular position of the Sun at solar noon relative to the plane of the equator, depending on the time of year (positive value for the northern hemisphere);

ω - is the latitude of the area (positive for the northern hemisphere);

γ - is the azimuthal angle of the plane, i.e., the deviation of the normal to the plane from the local meridian (the south direction is taken as the reference point, the deviation to the east is considered positive, to the west - negative);

ω - hour angle, equal to zero at noon for collectors oriented to the south, in an hour the value of the hour angle changes to 15 with a plus sign (from 12 o'clock to the morning) or minus (from 12 to the evening).

For reservoirs whose orientation differs by an azimuth angle r from the direction to the south, this angle with its sign must be added to 180 °. To determine solar radiation per hour of design parameters, it is necessary to add 15°/2 = 7.5° to the value of the hour angle of the start time of the estimated hour, i.e. for example, for the time from 11 a.m. to 12 p.m., take the solar radiation value of the hour angle as 1130.

Considering the above, the formula can be written as:

$\omega=180^0+\gamma-15^0 t+7,5^0$

$\delta=23,45\cdot\sin(360\times384+n/262)$, (3)

where n is the ordinal number of the day of theyear, as n is taken the number of solar radiation of the settlement day of the month for I - XII months of the year;

η_0 is a coefficient that takes into account real cloudiness conditions;

η_1 is a coefficient that takes into account the degree of transparency of the atmosphere (for Simferopol $\eta_1=1$).

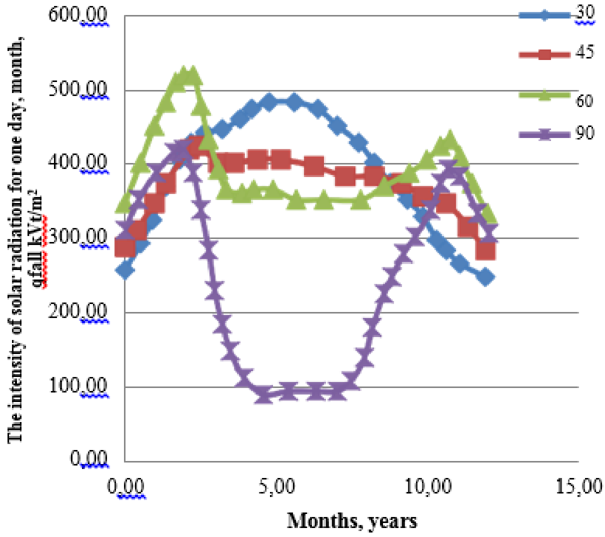
2.1 METHODS OF MODELING SOLAR BATTERY

Thus, the intensity of the heat flow, determined by formula (3), is a function of the season μ, time of day τ, tilt angle β and azimuth of the solar collector τ. It depends on the specific heat flux, which brings with it direct and diffuse solar radiation, which falls on the horizontal plane at the latitude of the given area.

Table 1. Methods of modeling solar battery.

№	Method	Explanation
1	Method for calculating the intensity of solar radiation by the method of coefficients	This technique will allow you to calculate the intensity of solar radiation that enters the surface of any spatial position every hour of daylight hours.
2	Method for calculating the intensity of solar radiation analytically	This technique will allow you to calculate the magnitude of the intensity of solar radiation incident on 1 m^2 of an inclined plane of the surface in every hour of daylight hours, under real conditions

Calculations were made according to formulas (1) and (3) for the city of Simferopol for a surface oriented to the south and plots of (Figure 1) were plotted. and (Figure 2) dependence of solar radiation inflow by (Figure 1). The intensity of the incident solar radiation per 1 m^2 of the surface at different angles of inclination to the horizon. Calculation according to the method [7].



Fegure 1: Dependence of solar radiation inflow.

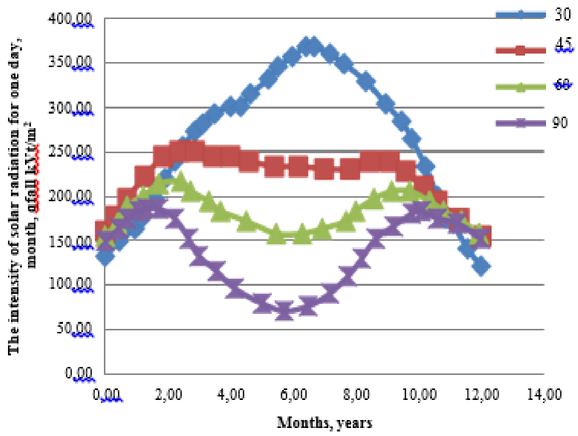


Figure 2: Intensity of the incident solar radiation per 1 m^2 of the surface at different angles of inclination to the horizon.

Figure 2 the intensity of the incident solar radiation per 1 m^2 of the surface at different angles of inclination to the horizon. Calculation according to the method [8].

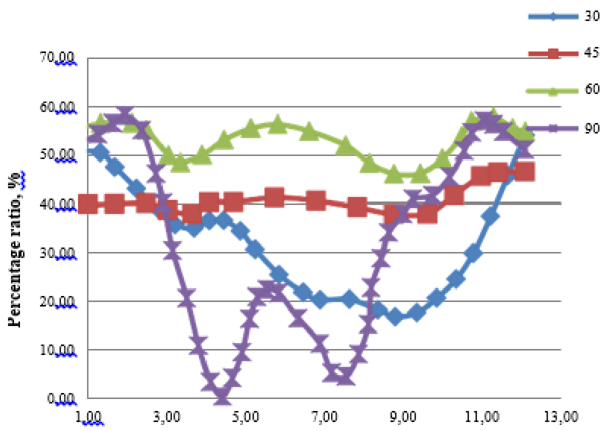


Figure 3: Solar radiation intensity for different tilt angles.

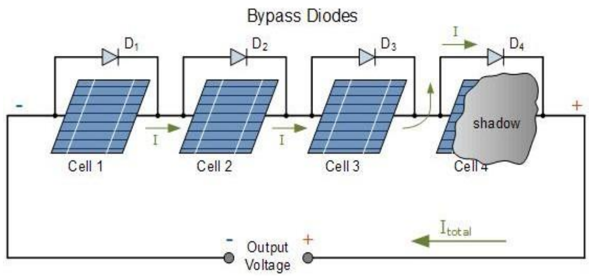
Figures 3. Percentage of solar radiation intensity for different tilt angles, calculated using various methods.

Various variants of the analytical model of the photocell are used to simulate the solar cell(SC) and solar battery(SB). A generalized SC model and several simplified versions of the model are implemented, and the simulation results are analyzed. It is shown that for photovoltaic applications, the shunt resistance of solar cells is considered large enough, and recombination in the region of the volume charge is negligible [9, 10].

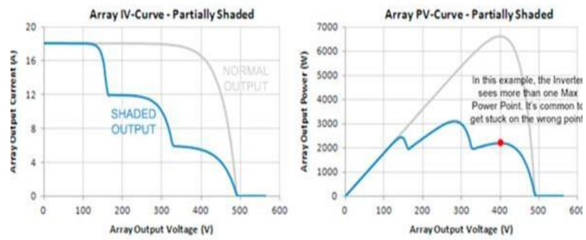
2.2 METHODS OF VAC

The simulation of the temperature characteristics of the solar system based on the built-in PSpice model of the diode is presented. This method of simulating temperature effects does not take into account changes in the photocurrent at different temperatures. Simulations of SC for various levels of ionizing cosmic radiation are performed [11, 12,13].

The SB model is presented and various cases of battery shading are described. The positive role of shunt diodes in SB is shown: they protect the battery operation when one of the elements is completely shaded, but reduce the output voltage of the system (Figure 4), analysis of power loss and degradation of the SB VAC during shading is quite a difficult task. Modeling the effect of arbitrary shadows on the SB characteristics makes it possible to estimate power losses for various shading options [14, 15, 16]



a)



b)

a)–SB of 18 SC with shaded photocells and shunt diodes; b)-comparison of the VAC of a partially shaded and non shaded battery.

Figure 4: Modeling of solar battery shading [17].

The convenience of using the PS pice language consists in the simplicity of describing the cases of shading of SB and shunt diodes in the battery design. The disadvantages of such a simulation language are bulkiness, the need to adjust the source files to set different environmental conditions, and the need to first describe the library and then the schematic components. This method of modeling does not allow you to easily switch from a single SC to an arbitrary SB configuration. To build a generalized SB model, you need to use a different simulation environment [18, 19, 20].

Analyzing the graph of the ratio of the total monthly income of the specific heat flux per 1 m^2, calculated using various methods, we can see that for an angle of inclination of 300, the percentage for the period June November fluctuates within 25%, for December, January-March about 45%, for April - June 35%. For a slope angle of 450, the ratio during the year is 40%. At an inclination angle of 600, the ratio of the total monthly inflow of the specific heat flux of 1 m^2 increases and amounts to 50% for different months. With an inclination angle of 900 for the summer months, the percentage varies from 5% to 20%, for the autumn, spring, winter periods - from 25% to 55% [21,22, 23].

The receiving area of the photovoltaic battery is oriented once a month according to the angle of inclination, which is determined by the formulas:

$$\beta_i = \varphi - \delta_i \qquad (4)$$

where φ is the geographic latitude of the area, degrees; δi - angle of declination of the Sun for a given month, deg. The declination of the Sun on a given day is determined by the Cooper formula (4). According to formulas (4), the optimal monthly angles of inclination of the photovoltaic battery for the city of Tashkent are shown in Table 2. The geographical latitude of the city of Tashkent is 41°15′52″. Optimum angle of inclination of the photovoltaic battery to the horizontal plane by months (degrees).

Table 2. The geographical latitude of the city of Tashkent is 41°15′52″.

Month											
Jan	**Feb**	**March**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
57	49	41	33	25	18	25	33	41	49	57	64

The calculation shows that for the spring and autumn equinoxes, the optimal angle of inclination is equal to the value of the latitude of the region. However, in the operation of a photovoltaic array, changing the orientation of the angle of inclination by months gives rise to difficulties. thus, the choice of the angle of inclination of the photovoltaic array is carried out in seasonal variations (winter, spring, autumn and summer) [24].

2.3.1 EQUATIONS

Knowing the insolation in this geographical location, we find that the minimum energy of solar radiation is typical for January and December. During these two months, the declination of the Sun (according to the analemma) is from -17.50 to -23.50. Solar radiation the magnitude of the angle of declination is determined through the solar radiation of the arithmetic cosines of these angles:

$$cos\delta_{cp} = \frac{\cos(-17{,}5)+\cos(-23{,}5)}{2} \qquad (5)$$

whence $\delta_{\text{solar radiation.}}$ =21.1^0 The optimal angle of inclination for the summer period;

$$\beta_{an.inc} = 41^0 - (-20{,}7^0) = 61{,}7^0 \qquad (6)$$

We will continue the calculations for the summer period (June and July):

$$cos\delta_{cp} = \frac{\cos(23{,}5)+\cos(18{,}5)}{2} \qquad (7)$$

whence $\delta_{\text{solar radiation.}}$ =21.1^0 The optimal angle of inclination for the summer period;

$$\beta_{an.inc} = 41^0 - 21{,}1^0 = 9{,}9^0 \qquad (8)$$

Below is the installation of a photovoltaic battery interms of the angle of inclination to the horizontal plane according to the seasons of the year in the conditions ofTashkent.

Table 3. The optimal angle of inclination of the photovoltaicarray to the horizontal plane by seasons of the year (deg.)

№	Winter	Spring and autumn	Summer
1.	~62^0	~41^0	~20^0

At the stage of developing a feasibility study for a solar heating system project, the choice of a method for calculating the influx of solar radiation intensity is important. As a result of the calculations, the graphs of the dependences of the total inflow of the specific heat flux per 1 m^2 during the year were obtained, calculated using various methods. The calculations showed that the amount of incoming heat calculated by various methods differs significantly.

CONCLUSIONS

A graph is given of the ratio of the values of the results obtained, in percent. The values of the total monthly inflow of the specific heat flux per 1 m^2 calculated by the analytical method take into account such factors as: the transparency of the atmosphere, the actual conditions of cloudiness, the movement of the Sun during the day in the celestial sphere, which have a significant impact on the final results of the calculation.

In Uzbekistan, solar and wind resources are monitored using automatic measurement systems. Long- term averaged weather data allows you to determine the optimal installation locations and types of solar and wind power plants that work effectively with such resources.

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