Low-power solar stations on dam surfaces of reservoirs

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Abstract. Agriculture in the Republic of Uzbekistan is based on irrigated agriculture, therefore, not all rivers existing in the country fully satisfy the needs of consumers, and water resources are accumulated mainly from reservoirs. From this point of view, the strength of the dams of these reservoirs has been studied in detail. However, in most cases, the external slopes of the dams of these artificial hydraulic structures are not used. This, in turn, requires new scientific solutions for the development of solar energy in Uzbekistan, where the amount of solar radiation is quite large. As an example, to study this problem, the amount of seasonal solar radiation in the southeastern region of the republic was obtained using simulation values using a geographic information system on the ArcGIS 9.3 platform and a seasonal map of solar radiation was developed. At the same time, to ensure the efficient operation of solar photovoltaic installations made of photovoltaic cells based on semiconductor silicon materials, it is proposed to use the external slope of the Talimarzhan dam located in this territory. This, in turn, makes it possible to eliminate the problem of preventing the drop in the coefficient of performance (COP) of solar photovoltaic cells, which is an important working part, with an increase in one of the most negative external factors - temperature.

The results show that based on the generated direct electric current from the solar photovoltaic station, the following can be supplied: lighting system for the reservoir, uninterrupted power supply of synchronous motors installed at pump station №7, consumers of auxiliary needs of the hydroaccumulative power station, which is planned to be installed in the reservoir, potential electricity consumption, consisting of from tourism services infrastructure to the development of ecotourism.

1. Introduction

In Uzbekistan, agriculture is based on irrigated land and the bulk of the water resources are accumulated through reservoirs. There are 56 reservoirs with large and medium capacity in the republic, and this in its place creates a large supply of water during the summer season. From this point of view, the strength of the dams of these reservoirs has been comprehensively studied [1, 2]. However, in most cases, from the outer surfaces of the dams of reservoirs with guaranteed durability, they are not used enough.

In Uzbekistan, the development of renewable energy sources is considered promising, mainly due to solar energy. Because the seasonal amount of solar radiation in the republic is a substantial amount relative to other regions of the globe.

By nature, solar radiation is considered an electromagnetic wave. The sunlight spectra are mainly divided into the following types within the wavelength range: 0.28...0.38 μm – ultraviolet, 0.38...0.78 μm visible (optical) and 0.78...3.0 μm - infrared, having a thermal effect. Of the above species,
ultraviolet and infrared lights are invisible. All spectra, without exception, have the energy of light (quantum energy).

In the atmosphere of green, solar radiation has the following types: direct radiation and scattered radiation in the atmosphere from particles, water vapor, and others. This radiation, in turn, forms the total radiation.

The amount of energy falling on a unit of the area during a unit of time depends on several factors. These include latitude and longitude, local climate, seasons, at what angle is a given surface relative to the sun [4].

The amount of solar energy falling on a given surface is directly related to the movement of the sun. This change will depend on the time of year and day. Usually, more solar radiation falls on the surface of the earth in the middle of the day than in the morning and evening. The sun, which is a source of energy, is in the middle of the day perpendicular to the horizon, reducing the distance that sunlight reaches the earth's surface through the atmosphere. The average annual amount of solar energy reaching the Earth’s surface varies depending on the time of winter and summer, as well as on the latitude of the Earth [4]. The closer you get to the equator, the more energy the unit generates. For instance; in the Central Asian region, daily energy consumption reaches 1000 kW·h/m² or more. This means that the amount of solar radiation can change dramatically depending on the season and latitude. It is necessary to take into account the above factors when using solar energy.

However, it is important to consider the influence of the external environment to ensure that the value of the efficiency of solar photovoltaic stations (SPS) is stable. One of these effects is the low temperature of the area where the photovoltaic station is located. With the increasing temperature of the photocells, a sharp decrease in the efficiency value was observed [11]. To prevent this problem, the use of the external relief of dams in reservoirs is promising. Because the presence of a large amount of water reserves ensures that the air temperature in the region is somewhat moderate. That is, this ensures that the convection process is slightly higher. This will provide a stable amount of electricity, which the photovoltaic plant must produce in its place. Silicon semiconductor material is the main raw material for the production of photovoltaic cells that convert solar energy directly into electricity and maximizes efficiency at relatively low temperatures (around \(-150 \div 100 \, ^\circ C\)) [11,17,18]. Their value varies depending on the crystal structure of silicon. For example, the efficiency of polycrystalline silicon-based solar cells is 17%. When the temperature of the photocell increases by 50 °C, the efficiency can decrease to 9% [12, 13, 8, 9, 15].

The Talimarjan reservoir in the Kashkadarya region of the Republic of Uzbekistan is located on the south-western side of Yangi-Nishon and has latitude and longitude coordinates: equal 38° 33 '27 " N, 65° 34'15" E [10], has a total volume of 1.5 billion m³ of water. This is one of the important objects of the economic development of the republic. There are two dams in the reservoir: the height of the "Dam-1" dam is 35 m, the length is 9745 m, the height of the "Dam-2" dam is 37 m, the length is 1000 m.[21].

Based on the current problem situation, this study is based on the development of a seasonal map of solar radiation using the ArcGIS 9.3 platform to estimate the magnitude of seasonal solar radiation in the Talimarjan reservoir in the southwestern part of the Republic of Uzbekistan, and at the same time, the aim of the study is to study the issues of obtaining scientific-technical calculations for the construction of a small solar photovoltaic station using the external slope of the Talimarjan artificial hydraulic engineering sky construction.

2. Methods
The possibilities of reaching the earth's surface of solar radiation can be modeled using geographic information systems (ArcGIS 9.3 platform) of seasonal and spatial changes in the balance of solar radiation in Uzbekistan, taking into account the potential of the natural and climatic conditions of each territory.
To do this, use the formula below [3, 4, 5, 6, 7]

\[ R_s(t) = R_D(t) + R_{Diff}(t) + R_O(t) \]  
(1)

where:  
- \( R_s(t) \) is the total value of solar radiation;  
- \( R_D(t) \) is the value of solar radiation in the forward direction;  
- \( R_{Diff}(t) \) is the value of diffusion of solar radiation;  
- \( R_O(t) \) is the value of reflection of solar radiation from the surface of the earth.

Global radiation (Global\(_{tot}\)) is calculated as the sum of direct (Dir\(_{tot}\)) and diffuse (Dif\(_{tot}\)) radiation of all sun map and sky map sectors, respectively.

\[ Global_{tot} = Dir_{tot} + Dif_{tot} \]  
(2)

We have analyzed bibliographic and internet data on the calculation of street lighting of various objects [14, 16, 19, 20]. From the analysis [14] it is seen that for local lighting it is allowed to use incandescent lamps in luminaires with non-translucent reflectors in the following cases:
- in the absence of requirements for the correct color rendering;
- if necessary, a certain and variable direction of light and when it is technically impossible to install lighting devices with fluorescent lamps.

3. Results and Discussion

If we use the above analytical expressions, we will be able to simulate solar radiation using existing software. The figure below shows the results of modeling seasonal solar radiation in Kashkadarya and Surkhandaryar regions.

So, to illustrate the importance of the above problem, let's calculate the sum and surface of all solar PV modules. First of all, we calculate the annual solar radiation as follows.

\[ E_{mid.}^{year} = \frac{\sum_{k=1}^{344} E_{mid}}{12} \]  
(3)

where: \( E_{mid} \) is the daily average radiation
If, for example, taking into account that the coefficient of a beneficial effect of the installed solar PV modules based on silicon polycrystal is $\eta = 14\%$, as a result, we are able to calculate the surface of solar PV modules with a consumer power of $P = 3000$W.
Figure 2. Topological view of the dam of the reservoir where the photovoltaic station should be installed: a) cross-sectional area, b) the position of blocks consisting of a set of photovoltaic modules on the active surface (top view)

\[ S_{spv} = \frac{P}{\eta_{spv, year}} = \frac{3000}{0.14 \cdot 395.3} \approx 55 m^2 \] (4)

We also determine the number of solar PV modules that make up this surface, as follows

Figure 3. Quantitative characteristic of seasonal solar radiation in Kashkadarya region by months
Figure 4. The amount of generated electricity per 1 m$^2$ of surface depending on the magnitude of seasonal solar radiation in Kashkadarya region.

Amount of power produced on the surface of 1 m$^2$ depending on the seasonal value of solar radiation in the territory of Kashkadarya.

\[ n_{\text{mod.}} = \frac{S_{\text{app}}}{S_{\text{1mod}}} = \frac{54.55}{0.99} \approx 55 \text{ pieces} \]  \hspace{1cm} (5)

From the above calculations, it is clear that we need to use modules with a significant surface for the construction of a small photovoltaic power plant with a certain capacity.

The following information is also noted here. For example, in outdoor lighting (BUT), you can use [14]: - LN for security lighting; at the entrances to the buildings; floodlight installations (along with the GLF); for architectural and decorative lighting; - DRL and DNaT lighting of territories of industrial enterprises, streets, squares, squares, parks; - DRI in floodlight installations for various purposes; - DCST when lighting large open spaces. However, the power of these lamps is 2-2.5 times greater than that of LED lamps (energy-saving lamps).

The point method can be used to determine the illumination at each point of an arbitrarily located plane at any location of the fixtures. This method is used in calculating the total localized, local, outdoor lighting, and lighting of vertical and inclined surfaces.

The calculation of the illumination of horizontal surfaces by the point method is carried out in the following order:

1. On the floor plan, fixtures are placed and control points are outlined on the illuminated surface, the illumination of which may be the least.

2. For each of the designated points determine the conditional illumination $E$ for a lamp with a luminous flux of 1000 lm:

\[ E = I_{\text{a.y.}} \cos^2 \alpha h \]  \hspace{1cm} (6)

where $I_{\text{a.y.}}$ is the conditional luminous intensity of a lamp with a lamp 1000 lm in the direction of the illuminated point (determined by the light distribution curves of the lamps or according to the table), cd; $\alpha$ is the angle between the axis of the lamp and the direction of the light beam.

Figure 6 shows a diagram for calculating the illumination by the point method when the surface is illuminated by one lamp. If the calculated point A is illuminated by several lamps, then the illumination at this point
\[ \sum e_A = e_{A_1} + e_{A_2} + \ldots + e_{A_n}. \]  

(7)

where \( e_{A_1}, e_{A_2}, \ldots, e_{A_n} \) is the illumination at the calculated point from each lamp.

In practice, the conditional illumination is determined by the spatial isolux graphs (Fig. 5) [14], which are a family of curves, i.e., the geometric location of points with the same horizontal illumination in the \( h \) and \( d \) coordinates at different ratios. For further calculation, take the point with the lowest conditional illumination.

![Figure 5. The scheme for calculating the illumination of horizontal surfaces by the point method](image)

3. The calculated luminous flux of the lamp is determined by the formula

\[ \Phi = 1000 \cdot E_{\text{min}} \cdot k / (\mu \sum e_A) \]  

(8)

where \( E_{\text{min}} \) is the minimum permissible illumination according to the standards, lux; \( k \) is the safety factor (taken the same as when calculating the method of additional illumination, taking into account the effect of remote fixtures and reflected light fluxes (taken from the directories). Typically, the value is selected within the range of 1.1 ... 1.2.

4. According to the calculated luminous flux \( \Phi \), a lamp of the corresponding power is selected in the catalog.

Figure 7 shows a diagram for calculating the illumination of inclined and vertical surfaces. Illumination of non-horizontal surfaces is determined by the formula

\[ E_{HG} = \psi E_G = (\cos \Theta \pm l \sin \Theta / h) \cdot E_G \]  

(9)

where \( l \) is the shortest distance from the axis of symmetry of the luminaire to the line of intersection of the inclined Mon at the vertical \( P \) plane with the auxiliary horizontal GH plane drawn through the calculated point \( A \); \( \Theta \) is the angle of inclination of the calculated plane to the horizontal. For vertical plane \( \Theta = 90^\circ \) and \( \psi = l/h \).
Batteries are the most important component in the installation of the solar system. Batteries store electricity from solar panels during day time and deliver this energy to the fixture at night. The life cycle of the battery is very important to the lifetime of light and the capacity of the battery will affect the backup days of the lights. The proper selection of batteries for PV systems depends upon the best knowledge of their design features, operational requirements, and performance characteristics. Batteries are manufactured by the combination of different sequential and parallel processes. Conduction of charging and discharging cycles on batteries is done necessarily before bringing them to the market for distribution to consumers. Important components of batteries are cells, active element, electrolyte, grid plate, separator, terminal posts, cell events, and case [16].

4. Conclusions
As a result of scientific research, the area where the dam is located will be able to use a seasonal map of solar radiation to increase the efficiency of solar photovoltaic devices installed for future use. At the same time, the tank’s lighting system from DC electricity, developed on the basis of a solar photovoltaic station, will provide consumers with electricity, a synchronous motor installed at pump station No. 7 (a synchronous motor excitation system with a vertical axis of the main pumps) to meet the needs of the planned hydroelectric station Further in the development of ecotourism around the reservoir, infrastructure maintenance (hotels, campsites, recreation areas, etc.) are potential consumers of electricity consumption.

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