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Prospects of Using Floating Solar Photovoltaic Power Stations in Hydro Accumulative Electric Stations

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Abstract

This article presents a theoretical study of power fluctuations when installing solar photovoltaic (PV) stations on land surfaces and water bodies. The prospects for utilizing floating solar PV stations in the reservoir of the planned "Piskent" hydro accumulative electric station were explored. Energy generation potential on land and water surfaces was forecasted using the performance ratio (PR).

Keywords Floating photovoltaic station, performance ratio, hydro accumulative electric station, tilt angle, volt-ampere characteristics, volt-watt characteristics.

Introduction

The global energy sector today demands the production of energy using affordable, sustainable, and renewable resources. By the 21st century, the depletion of non-renewable resources, dependency on oil, and scarcity of limited natural resources have created significant material and political challenges for countries. The release of harmful gases such as sulfur and carbon dioxide into the atmosphere and the radiological hazards from nuclear power plants have further complicated ecological conditions. Producing electricity using semiconductor-based technologies has emerged as a crucial factor in meeting modern requirements.

For example, in the Republic of Uzbekistan, more than 340 days of solar energy per year contribute to the transmission of over 2,200 MW of electricity through photovoltaic power stations. Wind power projects exceeding 500 MW have also been implemented. Hydropower stations currently generate over 2,000 MW, accounting for 17% of the country's total energy generation. However, recent analyses indicate that Central Asia may face severe drought challenges by 2030. In such circumstances, enhancing the capabilities of hydroelectric stations, improving their efficiency, and resolving resource issues positively are imperative [1,3].

At the initiative of government and executive authorities, the preliminary phase of constructing four hydro accumulative electric stations in cooperation with France and the People's Republic of China has begun. These include the "Khojakent" (200 MW), "Yuqori Pskem" (200 MW), and "Qarateren" (500 MW) hydro accumulative electric stations, as well as an additional 120 MW capacity station in the Pskem region of Tashkent Province. Together, these stations are expected to generate more than 1,200 MW of electricity upon commissioning [2,7,8].

The construction of these hydro accumulative electric stations involves creating artificial reservoirs. Installing solar photovoltaic power stations in these reservoirs represents an optimal solution for additional electricity generation and efficient land use.

THEORETICAL BACKGROUND

A significant challenge for photovoltaic stations today is dust accumulation and temperature increases on the surface of PV panels. Floating solar PV stations installed on water surfaces can substantially enhance energy output. The relationship between photovoltaic panel power and temperature can be described by the following formula:

$$P(T) = P_{STC} (1+\beta (T-T_{STC})) \quad (1)$$

here P_{STC} – Power under standard test conditions (STC), β – temperature coefficient of the panel, T – actual temperature of the panel, T_{STC} – tandard test condition temperature, typically 25°C [4,7].

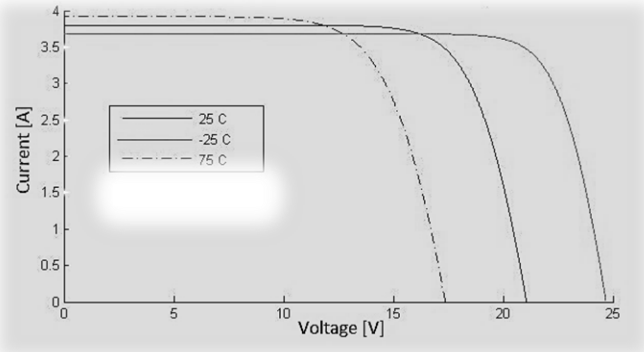

Fig. 1 The Volt-ampere characteristics of a solar panel at different temperatures.

As seen in the diagram, as the temperature increases, the current increases, while the voltage decreases. Conversely, when the temperature decreases, the voltage increases, and the current decreases. At a temperature of 25°C, the panels achieve maximum energy production efficiency. By reducing the temperature, the water surface serves as a natural absorber, helping to maintain optimal performance.

Fig. 2: Solar photovoltaic station installed on the surface of a natural hydro accumulative electric station reservoir.

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Typically, photovoltaic panels installed on the surface of water bodies are set at a tilt angle of 0°. However, in the case of Tashkent city, the optimal angle of solar radiation incidence is 35°. This optimal angle for solar energy collection is crucial for maximizing the performance of the photovoltaic station. The calculation of the optimal installation angle for a specific location takes into account factors such as geographic coordinates, time of year, and the position of the sun relative to the Earth's surface. The installation of floating solar photovoltaic stations in hydro accumulative electric station reservoirs offers a promising solution for increasing energy production. These stations can take advantage of the natural cooling effect of water, improving panel efficiency. In addition, the specific tilt angle of 35° in Tashkent city helps to achieve optimal energy generation, ensuring that solar panels absorb the maximum amount of sunlight throughout the year [5].

$$\cos(\theta)=\sin(\delta)\cdot\sin(\phi-\beta)+\cos(\delta)\cdot\cos(\phi-\beta)\cdot\cos(h) \quad (2)$$

Here, δ is the solar declination angle, Φ is the geographic latitude, β is the tilt angle of the panel, and h is the solar hour angle. The solar declination angle (δ) represents the angle between the rays of the sun and the plane of the Earth's equator, which varies throughout the year due to the Earth's axial tilt. The geographic latitude (Φ) defines the location's distance north or south of the equator. The tilt angle (β) is the angle at which the solar panels are installed to maximize energy production based on local solar radiation. The solar hour angle (h) describes the position of the sun relative to the time of day, which changes as the Earth rotates. The optimal tilt angle for a given location is often calculated based on these factors to ensure maximum efficiency in capturing solar energy. The relationship between the installation angle and power output can be expressed as follows:

$$P = P_{max} \cdot \cos(\theta) \quad (3)$$

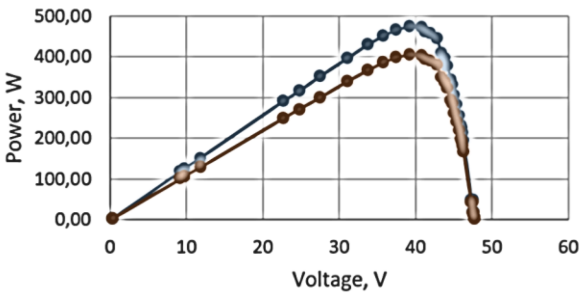

Fig. 3 – Volt-watt characteristics of the power dependence on the tilt angle.

This figure would typically illustrate how the power output (in watts) of a photovoltaic panel changes with respect to different tilt angles. As the tilt angle adjusts, it influences the amount of sunlight the panels receive, thus impacting the voltage and overall power output. The graph would typically show an increase in power output as the tilt angle approaches the optimal angle for the given location, after which further increases in tilt angle may lead to diminishing returns.

The efficiency coefficient (performance ratio) plays an important role when comparing the power of photovoltaic stations installed on land and at water level. The annual optimal power output of photovoltaic stations is calculated using the following formula.

$$P_y = P_{STC} \cdot E_y \cdot PR \quad (4)$$

Here, E_y is the average annual solar radiation, and PR is the performance ratio.

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RESULTS

Below is a comparison of the performance ratio of photovoltaic stations installed in the Piskent reservoir and on land.

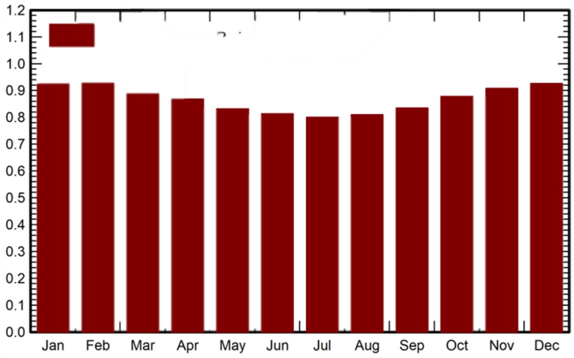

Fig. 4– Performance ratio (PR) when located at water surface (0.85)

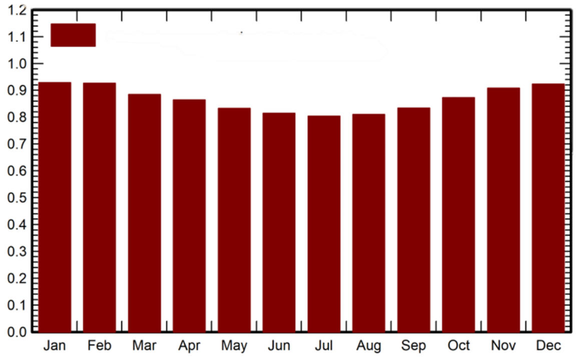

Fig. 5 – Performance ratio (PR) when located on land surface (0.82)

Below is a comparative graph based on the energy forecast of the annual electricity production of a 5 kW photovoltaic station installed in the Piskent reservoir.

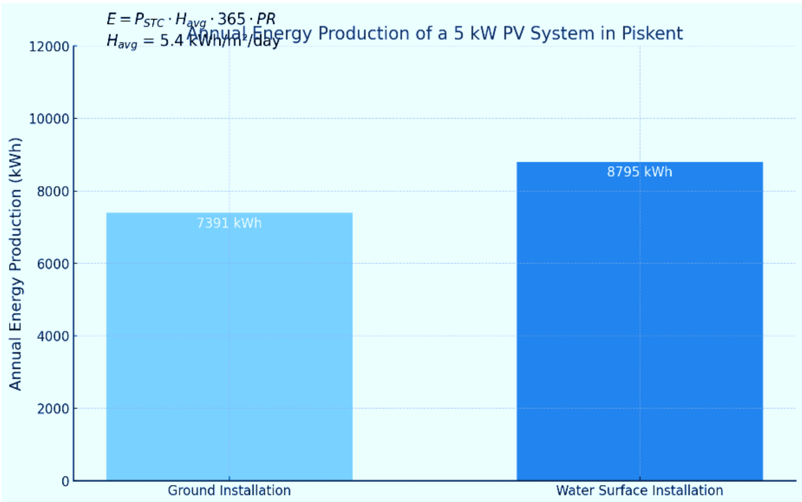

Fig. 6- Annual energy production of 5 kW PV System in Piskent

CONCLUSION

As seen from the graph, the photovoltaic station produces an additional 1,404 kWh of energy annually. This increases the potential for using electricity for various purposes. Overall, the installation of photovoltaic stations in hydroelectric station reservoirs helps achieve the intended goals. According to the research conducted, the performance ratio of floating photovoltaic stations is 0.2–2 higher than those installed on land. The disadvantages of floating photovoltaic stations include operational difficulties, corrosion in the solar panels, and freezing during the winter season. However, these issues are technically easy to resolve and do not significantly affect operations.

In the context of the Republic, the use of hydro accumulative electric stations for energy production is effective from an energy and resource standpoint, although economically it is considered less profitable. Constructing such projects based on public-private partnerships and utilizing them for achieving energy independence will pay off in the long term.

REFERENCES

1. O. Glovatskii, A. Yangiev, N. Nasyrova, A. Gazaryan, D. Adjimuratov and Sh. Azizov Results of field tests of the pumping station of the Karshi main canal (2023) https://doi.org/10.1063/5.0113299
2. Trajectory of sediment deposition at the bottom of water intake structures of pumping stations, Urishev B., Artikbekova F., Kuvvatov D., Nosirov F., Kuvatov U. IOP Conference Series: Materials Science and Engineering, Vol. 1030, No. 1, pp. 012137, 2021.
3. Reduced Pump Power Consumption Micro Accumulating Power Plants, Nosirov F., Urishev B.U., Ulugov B., Dustmurodov J., Khaliyarov P. International Journal of Advanced Science and Technology, Vol. 29, No. 7, pp. 2128–2136, 2020
4. Decrease of silting in a forebay of amelioration pump stations, Urishev B.U., Mukhammadiev M.M., Nosirov F., Zhuraev S.R. Urban Construction and Architecture, Vol. 3, No. 4, pp. 49–53, 2013.
5. Hydrometallurgical processing of copper-smelting dust, Matkarimov S.T., Yavkochiva D.O., Berdiyarov B.T., Nosirov F.D. International Journal, Vol. 8, No. 7, 2020.
6. A device for reducing the siltation of the front chamber of the pumping station in irrigation systems, Urishev B., Eshev S., Nosirov F., Kuvatov U. E3S Web of Conferences, Vol. 274, pp. 3001, 2021
7. Nosirov, F.J., 2024. IMPLEMENTING A SOLAR PHOTOVOLTAIC STATION IN WATERING SYSTEMS UTILIZING COMPLEX SOFTWARE. Technical science and innovation, 2024(1), pp.44-51.
8. https://www.gazeta.uz/oz/2021/04/15/gaes/