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RESOURCES OF THE GROSS HYDROPOWER POTENTIAL OF THE AMU-BUKHARA CANAL USING SINGLE-POINT AND TWO-POINT METHODS

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ABSTRACT: This article assesses the hydropower potential of the Amu-Bukhara Canal in the Bukhara region. To evaluate this potential, both single-point and two-point methods were used, along with the GR-70 hydrometric device to measure water discharge and flow velocity. According to the study results, the average annual water discharge for 2024 on a 70 km section of the Amu-Bukhara Canal was 117.8 m³/s, with a flow velocity ranging from 0.5 to 2 m/s. The two-point method was found to be more accurate, estimating the average annual energy generation at 1.5 million kWh. Based on these findings, it is scientifically proven that this irrigation canal can accommodate low-power micro-hydroelectric plants.
KEYWORDS: Amu-Bukhara Canal, hydrometric device "GR-70", gross water flow potential, water discharge, water flow velocity, "single-point" and "two-point" methods.

I.INTRODUCTION

The use of renewable energy sources offers numerous benefits, including reducing greenhouse gas emissions and decreasing dependence on fossil fuel markets, particularly oil and gas [1-3]. According to reports, greenhouse gas emissions in the Bukhara region increased by 30% between 2010 and 2024 [4]. The expansion of renewable energy can significantly mitigate the effects of climate change while also stimulating global employment by creating jobs in new power plants [5].

The Renewables 2024 Global Status Report estimates that renewable energy sources account for 27.3% of global electricity generation, with wind, solar, and hydropower being the most prevalent. Among them, hydropower is the leading source, contributing 15.9%, while solar and wind energy collectively account for 8% (Fig. 1) [6].

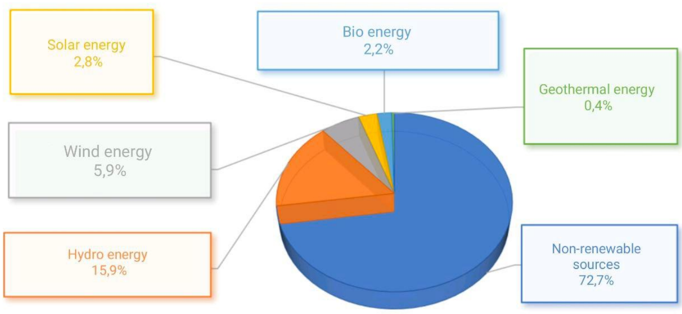

Fig. 1. Estimated share of renewable energy sources in global electricity

Taking into account environmental challenges, the President of the Republic of Uzbekistan has adopted the following resolutions:

Presidential Decree No. PP-2947 (May 2, 2017) – On the program of measures for the further development of hydropower for 2017-2021. Presidential Decree No. PP-3012 (May 26, 2017) – On the program of measures for the further development of renewable energy, improving energy efficiency in economic sectors and the social sphere for 2017-2021. Presidential Decree No. PP-3687 (April 28, 2018) – On additional measures for the implementation of investment projects in the field of renewable energy sources. Presidential Decree No. PP-4422 (August 22, 2019) – On accelerated measures to improve energy efficiency in economic sectors and the social sphere, introduce energy-saving technologies, and develop renewable energy sources. In accordance with these resolutions, Uzbekistan aims to gradually increase the use of renewable energy sources, establish new reliable and environmentally friendly power generation capacities, modernize existing hydroelectric power plants using advanced technologies, and enhance water resource management by adopting international best practices [7].

Between 2020 and 2030, according to the National Energy Strategy of the Republic of Uzbekistan, electricity generation from renewable energy sources is planned to increase to 30%. During this period, additional 30 GW of capacity is expected to be installed, including 3.8 GW from hydropower, 5 GW from solar energy, and approximately 3 GW from wind energy. As of today, Uzbekhydroenergy operates 37 hydroelectric power plants, generating 6.5 billion kWh annually [8].

One of the most important water supply complexes in Uzbekistan, serving the Bukhara and partially Navoi regions, is the Amu-Bukhara Machine Canal [9]. To implement hydropower projects, it is essential to first assess the hydropower potential of the Bukhara region's irrigation system. The availability of hydropower resources can facilitate the development of new hydropower plants, ensuring environmentally friendly, reliable, and uninterrupted electricity supply to remote areas of the Bukhara region that lack access to the centralized power grid [10].

When studying the hydropower potential of rivers and irrigation systems, various methods of water resource assessment are used. One of the most important traditional approaches is field surveys, along with data collection from meteorological stations. For example, Nathan Roman et al., in their research, presented the results of exploratory studies aimed at identifying hydropower potential in Western Malaysia for micro-hydroelectric power plants. To determine this potential, data was obtained from sources such as the Department of Surveys and Cartography of Malaysia and the Meteorological Department of Malaysia.

According to the study, 109 high-pressure sites (with a head of more than 50 meters) were examined, revealing an estimated total capacity of 20.4 MW [11].

Ilaria Butera and Roberto Balestra, in their study on the hydropower potential assessment of irrigation channels in the Piedmont region of northwestern Italy, proposed a method for identifying and characterizing irrigation networks with high hydropower potential. Their approach allows for determining the installed capacity of small hydropower plants and evaluating their efficiency. According to the study, the hydropower potential of this region ranges from 3.5 MW to 9 MW [12].

Some locations within the irrigation system may have greater potential than others but can be overlooked due to their remoteness or difficult terrain, leading to additional time and financial costs. However, the integration of GIS software enables remote sensing, significantly simplifying hydropower potential assessment.

Entin Hidayah et al., in their study, proposed a method to identify potential sites on the Ravatamtu River (East Java) with good hydropower potential for the construction of hydroelectric power plants, based on two main factors: the presence of a steep slope and maximum water flow. To determine these parameters, as well as to define catchment area boundaries and the river network, the ASTER GDEM 2 software was used, selecting the longest section for analysis. According to the study, the hydropower potential in this area can reach 653 kW [13].

In his research on the gross hydropower potential of the Murat River in southern Turkey, Sadik Alashan applied the double-point method, the hypsographic curves method, and the gross hydroelectric power calculation method (Areal Gross). The study found that the gross hydropower potential of the area was 2,185 MW, nearly twice the estimate from the single-point method (933 MW) and the hypsographic curves method (974 MW) [14].

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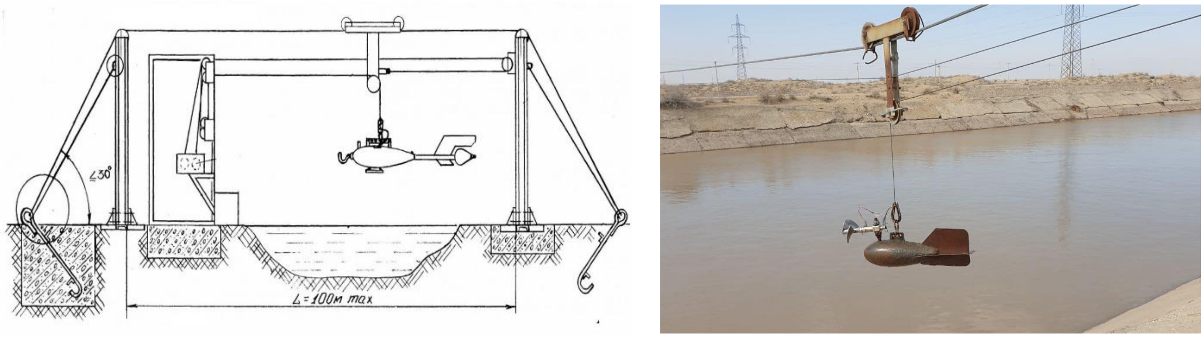
There are electricity-related problems in this region, such as frequent power outages due to shortages and the absence of power lines in remote areas of the Bukhara region. To address this issue, it is necessary to assess the hydropower potential of the region to design a hydropower plant that operates efficiently in low-pressure irrigation streams, thereby increasing electrification levels in remote areas of the Bukhara region [15-17].

II. METHOD AND MATERIALS

Gross hydropower potential is defined as the annual energy that could be generated if all natural flows at all locations were utilized without any energy loss. In practical applications, the hydroelectric potential of a watercourse is calculated using two classical methods with relatively simple formulas, allowing the estimation of gross hydropower potential based on water flow rate and head. These methods include single-point and two-point techniques.

To identify the hydropower potential in the Bukhara region, exploratory studies such as cartographic and hydrological surveys were conducted. For both aspects of the study, topographic maps and meteorological data were used to estimate the head and flow velocity of potential hydropower sites, using a hydrometric device. Figure 2 (a) presents a diagram of a hydrometric installation, while Figure 2 (b) illustrates the measurement process using the GR-70 hydrometric device for water flow assessment.



(a) (б)

Fig. 2. GR-70 Hydrometric installation for measuring water flow in rivers

a) Scheme of the hydrometric installation, b) Process of measuring the water flow on ABC-1 (Amu-Bukhara Canal-1)

When assessing hydropower potential, it is essential to determine water head and flow rate. According to Building Codes and Standards 2.06.03-85 Reclamation Systems and Structures. Irrigation Channels and Networks, the height difference in hydropower potential assessment corresponds to the slope of the irrigation channel, which is approximately 5 cm per kilometer. Table 1 presents the average monthly water consumption of the Amu-Bukhara Canal for the year 2024.

Table 1.

Month	**Water consumption, (m^3/s)**	**Month**	**Water consumption, (m^3/s)**
January	69,1	July	176,8
February	79	August	168,3
March	93,4	September	109,1
April	89,4	October	66,8
May	145,2	November	105,1
Jun	174,6	December	136,3

SINGLE-POINT METHOD

This most commonly used practical formulation is useful for preliminary calculations of hydroelectric power, P, which expresses it as equal to γ times the discharge Q, multiplied by the falling head H:

$$P = \gamma \ Q \ H \qquad (1)$$

where: γ - specific weight of water in kN/m³, Q - water discharge in m³/s, H - head in meters, P -power in kW.

This method is applicable for assessing the gross hydropower potential at a specific point where water flow and head parameters have been measured.

DOUBLE-POINT METHOD

Equation (1) does not take into account certain topographic parameters of the watercourse, such as elevation changes along the main channel. Therefore, the results may not always be reliable. Considering head and discharge measurements at two locations provides more accurate results. In practice, two points are taken as the arithmetic mean of the watercourse height h_1 and another height h_2 at the outlet point. Consequently, a rational and logical approach leads to another version of equation (1) as:

$$Q_i = \frac{Q_1 + Q_2}{2} \qquad (2)$$

where Q_1, Q_2, and Q_i are the water discharge at the beginning, at the outlet, and in the middle of the watercourse, respectively.

$$h_i = \frac{h_1 + h_2}{2} \qquad (3)$$

where h_1, h_2, and h_i are the water head at the beginning, at the outlet, and in the middle of the watercourse, respectively.

Therefore, the power of the gross hydropower potential is calculated as:

$$P = \gamma \ (h_i - h_2) \ \frac{Q_i + Q_2}{2} \qquad (4)$$

where, γ - is the specific gravity of water in kN/m³, Q_2 -is the water flow rate at the outlet in m³/s, Q_i is the water flow rate in the middle of the watercourse in m³/s, h_2–is the water pressure at the outlet in m, h_i- is the water pressure in the middle of the watercourse in m, P - is the power in kW

III. RESULTS

The assessment of the gross hydropower potential was carried out on the section of the Amu-Bukhara canal at the junction of two channels, ABK-1 and ABK-2, with a length of 70 km to the Tudakul reservoir. The assessment took into account water flow losses directed to the Kalaulbazar branch, which supplies two pumping stations—Karaulbazar and Dustlik. Table 2 presents the calculated resource values of the gross (theoretical) hydropower potential in terms of capacity and energy.

Table-2

Month	Power (MW)	Energy (mln. kW·h)	Month	Power (MW)	Energy (mln. kW·h)
January	2,4	0,5	July	6,1	1,2
February	2,7	0,5	August	5,8	1,2

March	3,2	0,6	September	3,7	0,7
April	3,1	0,6	October	2,3	0,5
May	5,0	1,0	November	3,6	0,7
June	6,0	1,2	December	4,7	0,9

Figure 3 presents a diagram illustrating the resources of the gross (theoretical) hydropower potential for the section of the Amu-Bukhara canal, considering the water flow rate for the year 2018.

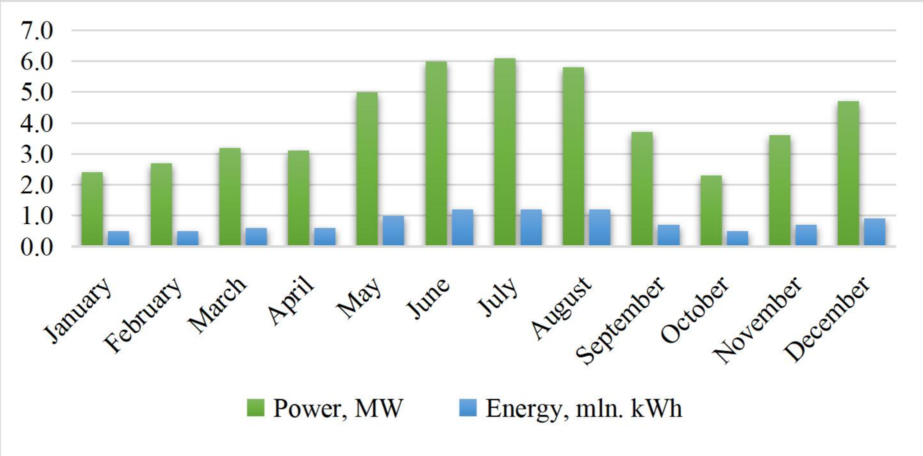


Fig. 3. Gross hydropower potential for the period of 2024 for the section of the Amu-Bukhara Canal using the single-point method.

Table 3 presents the water flow data measured at two points, at the beginning and end of the watercourse, for the section of the Amu-Bukhara Canal during the 2024 period, considering the water flow diversion to the Karaulbazar branch.

Table-3

Month	**Q_1, (m^3/s)**	**Q_2, (m^3/s)**	**Month**	**Q_1, (m^3/s)**	**Q_2, (m^3/s)**
January	69,3	69,1	June	197,3	176,8
February	86,7	79,0	August	186,9	168,3
March	110,0	93,4	September	118,9	109,1
April	104,2	89,4	October	76,6	66,8
May	162,7	145,2	November	111,4	105,1
June	188,1	174,6	December	136,3	136,3

Table 4 presents the calculated water flow values in the middle of the watercourse, determined using the two-point method, along with the resources of the gross (theoretical) hydropower potential for the Amu-Bukhara Canal section, considering water consumption for the 2024 period.

Table-4

Month	**Q_i, (m^3/s)**	**P, (MW)**	**E, (million kW·h)**		**Q_i, (м³/с)**	**P, (MW)**	**E, (million kW·h)**
January	69,2	1,2	0,9	July	187,0	3,1	2,2
February	82,8	1,4	1,0	August	177,6	3,0	2,1
March	101,7	1,7	1,2	September	114,0	1,9	1,4
April	96,8	1,6	1,1	October	71,7	1,2	0,9

May	153,9	2,6	1,8	November	108,2	1,8	1,3
June	181,4	3,1	2,2	December	136,3	2,3	1,7

Figure 4 presents a diagram illustrating the resources of the gross (theoretical) hydropower potential for the Amu-Bukhara Canal section, considering water consumption for the 2024 period, calculated using the two-point method.

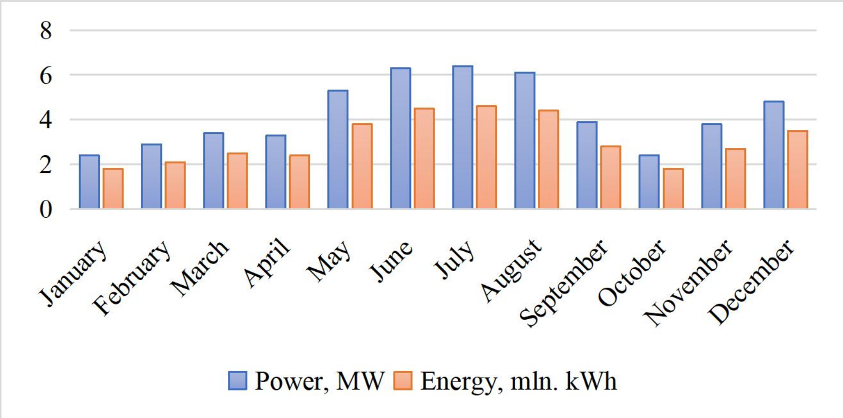


Fig. 4. Gross hydropower potential for the period of 2024 for the section of the Amu-Bukhara Canal using the two-point method

III. CONCLUSION

During the assessment of the gross hydropower potential of the 70-kilometer section of the Amu-Bukhara Canal irrigation system, the GR-70 hydrometric installation was used. It was found that the water flow rate ranges from 0.5 to 2 m/s, and the average annual water consumption is 117.8 m^3/s. The scientific substantiation of gross hydropower potential resources has shown that the two-point method is the most accurate and provides better results compared to the single-point method, according to which the average annual energy was 1.5 million kWh and 0.8 million kWh, respectively. The study showed that the Amu-Bukhara Canal has good hydropower potential and can serve as a solution to problems with the electrification of remote areas, ensuring uninterrupted and reliable electricity supply through micro-hydropower plants operating efficiently in low-pressure watercourses.

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