Usage of Low-Pressure Water Sources and Hydroturbines Working in Them

Bozarov Oybek Odilovich
PhD, doctoral student of Tashkent State Technical University (DSc)
Email: obozarov7@inbox.ru
Kozimjonov Nozimjon Azimjon o‘g‘li
Andijan Institute of Mechanical Engineering
Assistant of the Department of “Alternative Energy Sources ”
E-mail: kozimjonovnozimjon886@gmail.com

Abstract: The article examines the state of electricity production and the use of hydropower sources in the Republic of Uzbekistan, and the effectiveness of the Jonval-Genshel hydro turbine of the micro hydroelectric power plant designed to use the existing low-pressure water sources in the republic.

Key words: Hydropower potential, speed triangle, hydroturbine, jet, active, micro hydropower plant.

Introduction

According to statistics, the production of electricity using alternative energy sources in the Republic of Uzbekistan in 2021 amounted to 147 MW. 2,043 MW of this electricity is used for hydropower, 1 MW for wind energy, and the remaining 104 MW for solar energy [1].

From these data, it can be seen that although low-pressure hydropower potentials are sufficient for the production of electricity from alternative energy sources, it is a very low indicator due to the fact that it is not used wisely.

The reasons for the above situation can be explained as follows. Existing methods are the linear accounting method or the automated calculation of the gross hydropower potential of rivers using geographic information systems (GIS). The GIS server technology is based on the hydropower potential of all parts of the water source, based on the difference between the upper and lower beefs of the river flow [2 - 11]:

$$N = \sum_{i=1}^{n} N_i = \sum_{i=1}^{n} \left[g \cdot \left(\frac{Q_{H_i} + Q_{K_i}}{2} \right) \cdot H_i \right] \qquad (1)$$

here, N – gross potential, kW;
i – river section number;
g – acceleration of free fall, m/s^2;
Q_{H_i} – water consumption m^3/s at the beginning of the i-part of the river;
Q_{K_i} – water consumption m^3/s at the end of the i-part of the river;
H_i – is the difference in flow rates in the i-th part of the river, m.

It can be seen from the above that the technical potential for the construction of small and large hydroelectric power plants was calculated. For the construction of micro hydropower plants operating in flowing waters and low-pressure water sources, the calculation of their technical hydropower potential should be evaluated in relation to the total kinetic energy of the water flow.

In hydropower projects, hydropower potential areas for the construction of mini-hydroelectric power stations have been determined, but low-pressure areas of water sources such as canals, rivers, and canals flowing through the territory of the republic have not been taken into account. Their number, capacity, location, and types of micro-hydroelectric power plants that can be installed in them have not been determined.

Places where 4-5 meters of pressure can be created in water sources are rare along the length of the river. The depth of canals, canals and rivers is 0.5-3 meters. The fact that active working wheels that work effectively in such places are not sufficiently improved is the reason for not using such resources [12].

Therefore, it is necessary to create a micro HEP (hydro electric plant) system that works efficiently at low pressures of 2-4 meters, to create structures with optimal parameters of the hydro turbine, which is the main working device, and to improve the existing ones, to determine the hydropower potentials of low-

ISSN NO: 2770-4491
Date of Publication:07-01-2023

pressure, wastewater sources, the types of structures used in them and their installation locations. identification is an important task for field experts.

Active hydroturbines differ from ordinary waterwheels in that they have no or very small relative velocity of water passing through them. In active turbines acting by gravity from above and impacting the blades from below, the reduction of the speed of the water flow leaving the blades compared to the speed before the impact causes an increase in the efficiency of its useful work [12]. The water flow acting on the impeller exerts pressure on the blades by continuously changing the direction and value of its speed along the blades. After flowing through the channels formed by the blades on the working wheel, it is poured into the exit pool at a low speed. The lower the exit velocity compared to the initial velocity at the inlet to the impeller, the more energy is extracted from the water.

It is known that Francis type hydro turbines work efficiently at high pressures and high water consumption. But when used in low pressure water sources up to 5m, its efficiency (Efficiency) is very low. This is due to the fact that in the Francis radial axis hydroturbine, water enters in a radial direction through a diverter, and at the same time, in a vertical direction, it transmits pressure to the impeller blades and exits through the blades in an almost horizontal direction. At low pressure and low water consumption, the diameter of the hydro turbine impeller is very small. This condition, in turn, causes the water flow in the impeller to move closer to the central shaft, as a result, the kinetic moment of the hydro turbine shaft, the power moment decreases, and the efficiency of the hydro turbine is 45-53% [13, 14].

Because the flow of water naturally moves from the upper level to the lower level, vertical axis hydro turbines are often used. However, it often becomes difficult for them to get water into the working wheel with an increase in the frequency of rotation, sometimes this phenomenon is also observed in the guiding device. Let's consider the Johnval-Genshel turbine operating at low pressures.

Shortly after Fourneyron, among the proposed jet turbines, the turbines of K. A. Genshel (Germany, 1837) and N. Jonval (France, 1843) were the most widely used in practice. Henschel and Jonval independently created a similar turbine in terms of construction at the same time [15]. In both cases, the blades along the perimeter of the cylinder attached to the shaft are in the form of one piece of spiral shape, and the blades are parallel in the vertical cylindrical section. A diverter device was placed above the working wheel, and the water inflow to its diverter blades began vertically, and the lower part continued parallel (Fig. 1).

In order to calculate the energy that can be extracted from the water flowing through the Jonval-Genschel hydroturbine, it is necessary to determine the relationship between the velocities of water entering and leaving the impeller and the circulation of water in the blades. Figure 1 below shows a cylindrical cross-section of the guide gear and impeller.

The angle formed by the guide vanes with a plane perpendicular to the turbine axis is denoted by α_1, since the distance to the working wheel is very small, it can be considered that the water flow enters the working wheel at this angle, β - the said plane with the angle formed by the blade of the working wheel at the inlet, the angle formed by the water at the outlet. υ_1 is the absolute velocity of water at the outlet of the diverter.

In order for the flow of water from the guide vane to hit the working wheel with a shock and not lose energy, the relative speed of the flow ω_1 to the vane should coincide with the direction of the effort made at the entrance to the working wheel vane. In order to fulfill this condition, the absolute velocity of water υ_1 should be an equal product of relative velocity ω_1 and linear (extract) velocities u_1 at the considered point of the working wheel. So:

ISSN NO: 2770-4491
Date of Publication:07-01-2023

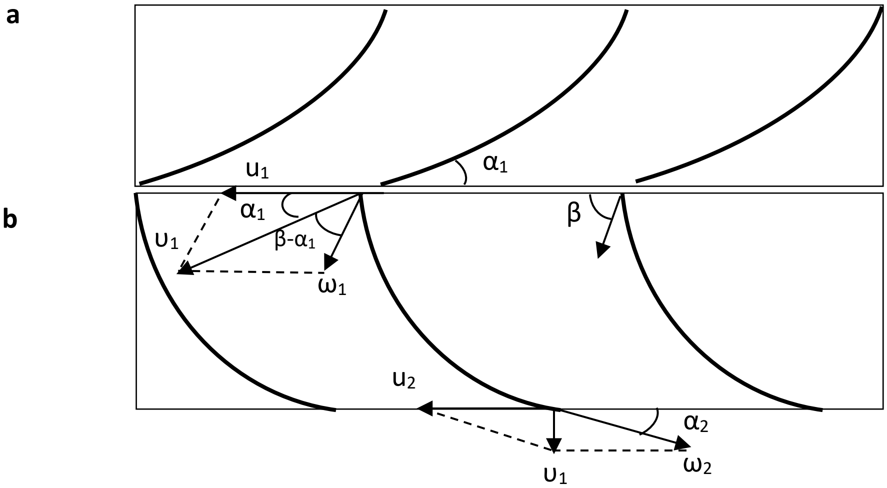

Figure 1. Cylindrical cross-section of Jonval-Genschel hydro turbine: a) guide device; b) working wheel.

$$\frac{u_1}{\sin(\beta-\alpha_1)}=\frac{\upsilon_1}{\sin\left(180^0-(\beta-\alpha_1+\alpha_1)\right)}=\frac{\upsilon_1}{\sin\left(180^0-\beta\right)}=\frac{\upsilon_1}{\sin\beta};$$

From this

$$u_1=\frac{\upsilon_1\sin(\beta-\alpha_1)}{\sin\beta}; \qquad (1)$$

The amount of water that flows through the diverter also passes through the impeller. The widths of the blades of the guiding device and the blades of the working shaft in the radial direction are equal. The width of the water outlet compartments on the lower plane of the guide device is proportional to $\upsilon_1\sin\alpha_1$, the amount of water coming out of the working wheel is proportional to $\sin\alpha_2$, then:

$$\upsilon_1\sin\alpha_1=\omega_2\sin\alpha_2,$$

it appears that $\omega_2 = u_1$ is necessary to achieve the smallest possible absolute velocity of water exiting the impeller. In that case:

$$\sin\alpha_2\cdot(\mathrm{ctg}\alpha_1-\mathrm{ctg}\beta)=1 \qquad (2)$$

In active turbines, the speed of water entering the impeller corresponds to the full value of the acting pressure, the speed does not increase during the further movement of water, so $\omega_1=\omega_2=u_1$.

Bundan kelib chiqadiki, u_1 va υ_1 tezliklarda qurilgan parallelogramm umumiy asosi υ_1 bo‘lgan ikkita teng yonli uchburchakdan xosil bo‘ladi. U holda $\beta = 2\alpha$. Agar yuqorida olingan tenglikda $\beta = 2\alpha$ ni almashtirsak:

It follows that the parallelogram built at speeds u_1 and υ_1 is formed by two equilateral triangles with a common base υ_1. Then $\beta = 2\alpha$. If we replace $\beta = 2\alpha$ in the equation obtained above:

$$\sin\alpha_2(1+\mathrm{ctg}^2\alpha_1)=2\mathrm{ctg}\alpha_1 \qquad (3)$$

If we simplify the expression (3):

$$\mathrm{Sin}\alpha_2=\mathrm{Sin}\,2\alpha_1; \qquad (4)$$

Olingan ifodada α_1 burchak odatda 25^0-35^0 oralig‘ida o‘zgaradi, bunda aktiv turbinalar uchun β burchak 50°-60° oralig‘ida bo‘ladi va gidroturbina yaxshi samaradorlikda ishlaydi. Aytaylik, $\alpha_1 = 25°$, (4) formuladan $\alpha_2= 50°$ ni olamiz. Bu xolda absolyut chiqish tezligi juda katta bo‘ladi. Bundan kelib chiqadiki, ishchi g‘ildirakning qismlari bir xil kenglikda bo‘lishi kerak.

In the resulting expression, the angle α_1 usually varies between 25^0-35^0, while for active turbines, the angle β is between 50°-60°, and the hydro turbine works with good efficiency. Suppose $\alpha_1 = 25°$, from formula (4) we get $\alpha_2= 50°$. In this case, the absolute output speed will be very high. It follows that the parts of the working wheel should be of the same width.

On the basis of the above considerations, the development of a small model of a bladed jet hydro turbine, described below, was experimentally tested. Photographs of the working wheel model of the micro-HE hydro turbine prepared for experimental testing are presented below (Fig. 2).

a) b)

Figure 2. Model of micro-HEP jet hydro turbine working wheels: a) 200 W power; b) with a power of 1 kW;

The 200 W model of the proposed micro-HEP hydro turbine was experimentally tested by the authors on a specially prepared laboratory stand. As a result of the experiment, the efficiency of the proposed hydro turbine was 45-54% according to the value of water consumption and water pressure.

The following conclusions follow from the above considerations:

- in hydroturbines with a guide device, using the formula (4) derived from the speed triangle, it is possible to choose the water output speed in accordance with the angles of entry and exit of the blades of the working wheel and thereby control the efficiency of the hydroturbine.

- if the blades of the Johnval-Genschel hydro turbine are not parallel in the water outlet, and a narrowing outlet is formed, this hydro turbine works like a jet hydro turbine, and a Francis type hydro turbine is formed, which works with high efficiency at low pressures due to the increase in the power shoulder.

In practice, the use of the above considerations and analysis of hydro turbines in the production of electricity from low-pressure water sources leads to an increase in the efficiency of micro hydropower plants.

References

1. https://podrobno.uz/cat/economic/proizvodstvo-elektroenergii-v-uzbekistane-eto-ubytochnaya-otrasl-s-tochki-zreniya-chastnykh-investor/
2. Баденко .Н.В.,Баконовичус Н.С., Воронков О.К., Иванов Т.С., Ломоносов А.А., Петрошенко М. В. Разработка методологического обеспечения процесса автоматизированного вычисления гидроэнергетического потенциала рек с использованием геоинформационных систем. Инженерно-строительный журнал, №6, 2013, URL: http://www.engstroy.spb.ru/index_2013_06/ivanov.pdf
3. Felix J., Dubas A, Use of GIS to identify potential sites for small hudroelectricplants;general concepts and example of application. URL: http//www.stucky.ch/en/contenu/pdf/GIS_to_identify_potential_sites_for_small_
4. Punys P., Dumbrauskozs A.,Vyciene 6 Tools For small Hydropower plant resaurseplanning.,And development; A review of technology and applications//Energies.2011. Vol.4,P.p.1258-1277.
5. Толстихина Л. В. Голований Е.Н., Плетенкин А. Д., Расчёт гидроэнергетического потенциала рек на территории хакасии с применением ГИС-технологий, ГИДРОЭЛЕКТРОСТАНЦИИ В XXI ВЕКЕ
Сборник материалов IV Всероссийской научно-практической конференции молодых ученых,

ISSN NO: 2770-4491
Date of Publication:07-01-2023

специалистов, аспирантов и студентов. 2017, С.57-61. URL:https://elibrary.ru/item.asp?id=29019817.

6. Dante G. Larentis, Walter Collischonn,FranciscoOlivera, Carles E.M. Tucci.Gis-baset procedures for hydropower potential spotting//Energy.2010.Vol.35 P.p 4237-4243.
7. Hall D., Cheery S,J., J Rewes,K,S. Lee.R.RCarrol G.R Sommers G.L Verdin R,L., Water EnergyResources of the United States with Emphasis on Low Head/Low Power Resources/Idaho National Engineering and Environmental Labaratory,2004.URl: http//hydropower/inel.gov/recourceassessment/pdfs/03-
8. Feizizadeh B., Haslauer E.M GIS-based procedure of hydropower potential for Tabriz basin,Iran //GI_Forum 2012, Salzburg,Asutria.July 3-6,2012.P,p.492-502.
9. Fitzerald N., Arantegui R., McKeoghE.,Leahy P.A GIS baset model to calculate the potential for transforming conventional hydropower schemes and non-hydro reservoirs to pumpet hydropower schemes//Energy.2012.Vol.41 Pp.483-490 pp.
10. Ballence A., Stephonson D., Chapman R.A., Muller J.A geographic information systems analysis of hydro power potential in South Africa // Journal of Hydroinformatics. 2000.Vol.2, No.4, Pp.247-254.
11. Алиев Р.У., Бозаров О.О., Абдуқаххорова М., Ўзбекистонда кичик гидроэлектр энергия манбаларини ривожлантиришнинг долзарб шартлари. Илмий хабарнома, АДУ, 2018, №1, 16-23 б.,
12. Bozarov O.,Usarov Kh., Kiryigitov B.Prospects for providing decentralized areas with renewable electricity. /International Journal for Innovative Engineering and Managment Reseaech, Vol 10 Issue 09, September 2021, ISSN 2456 – 5083.3.
13. J.C.Casila, M.Duka, R.D.L.Reyes, J.C.Ureta, Potential of the Molawin creek for mikro hydro power generation: An assissment.//Sustainable Energy Technologies and Assissments.-Phillipines, 2019, -Vol.32.P.P.111-120.
14. D. Zhou, J.Gui, D.Deng, H.Cheu, y.Yu, A.Yu, C.Yang. Development of an ultralow head siphon hudro turbine using computational fluid dinamics.// Energy.-China, 2019.-Vol. 181.-P.P. 43-50.
15. Моисеев Н. Д. Очерки истории развития механики. — М.: Изд-во Моск. ун-та, 1961.-478 с, 380 С.