Journal of Higher Education and Academic Advancement
Homepage : https://journal.antispublisher.id/index.php/EJHEAA
Email : admin@antispublisher.com

e-ISSN : 3032-1123
JHEAA, Vol. 2, No. 1, January 2025
Page 76-84

Technical and Financial Results of Obtaining Electricity from Micro Hydropower Plants

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DOI : https://doi.org/10.61796/ejheaa.v2i1.1209

Sections Info

Article history:
Submitted: December 27, 2024
Final Revised: December 27, 2024
Accepted: December 28, 2024
Published: December 28, 2024

Keywords:
Water flow rate
Generator
Water flow power
Electrical energy

ABSTRACT

Objective: *This study aims to analyze the efficiency and feasibility of micro-hydroelectric power plants in various geographical locations. It explores the fundamental principles of hydropower generation, emphasizing the potential of micro-hydro systems to provide sustainable electricity, particularly in remote areas. The research also evaluates the impact of different construction methods and turbine types on overall energy output and efficiency.* ***Methods:*** *The study employs a combination of theoretical analysis and practical calculations to determine the efficiency and feasibility of micro-hydro systems. The fundamental equation for power generation (P = 9.81 * Q * H * η) is applied to different scenarios. Various micro-hydro construction methods, including diversion and simple in-stream systems, are compared. Additionally, the performance of active and reactive hydroturbines is assessed, along with power regulation techniques such as frequency and voltage adjustment mechanisms.* ***Results:*** *Micro-hydropower plants demonstrate high efficiency, reaching up to 75-80%, significantly outperforming thermal power plants. The power output varies based on water flow rate, pressure head, and turbine efficiency. Proper site selection, considering factors like river slope and seasonal water stability, enhances performance. A case study calculation reveals that a micro-hydropower system with a flow rate of 3 m³/s and a head of 1.5 m can generate approximately 73.7 kW, enough to power several households. However, challenges such as seasonal fluctuations, construction costs, and environmental concerns, including ecosystem disruption, must be addressed.* ***Novelty****: This study provides a comprehensive comparison of different micro-hydro construction techniques and turbine types, offering practical insights for optimizing efficiency and sustainability. It highlights the importance of selecting appropriate locations and materials to maximize energy output while minimizing environmental impact. Additionally, the research explores innovative frequency and voltage regulation methods, which are crucial for maintaining stable energy supply in micro-hydro applications.*

INTRODUCTION

Hydropower is the sum of the kinetic and potential energies of a water flow. Any water flow has potential and kinetic energy [1], [2], [3]. A hydroelectric power plant is an object that converts kinetic and potential mechanical energy into electrical energy. The capacity of hydroelectric power plants is determined by the following formula:

$$P = 9.81 * Q * H * \eta \quad (1) \text{ (kW)}$$

Where: Q- water flow rate (m^3/s) H- water pressure head (m) η- the coefficient of efficiency of the hydroelectric power plant.

The efficiency of hydroelectric power plants is very high, twice as much as that of thermal power plants (thermal power plants have an efficiency of up to 40%, while hydroelectric power plants have an efficiency of up to 75-80%). The efficient operation of hydroelectric power plants depends on two important factors [4], [5].

The stability of the water flow throughout the year, that is, the flow is regular throughout the year [6], [7]. The location of the river on which the hydroelectric power plant is being built is as steep as possible [8], [9], [10]. To increase the capacity of large-capacity hydroelectric power plants, artificial hydraulic engineering measures are carried out [11]. For example, dams are built to increase the pressure of water on the riverbed. In mountainous areas, special diversion channels are built. According to their capacity, hydroelectric power plants can have a capacity of from 100 watts to 10,000 MW. They are classified into groups according to their capacity. Hydropower plants with a capacity of more than 100 MW are considered large-capacity, while the remaining hydropower plants are called small and micro hydropower plants. A large-capacity hydroelectric power plant requires a very large infrastructure [12], [3]. In particular, a huge amount of money, raw materials necessary for construction, high-voltage, high-capacity electricity consumers, etc. In addition, the technology for building large-capacity hydroelectric power plants is also very complex. The need to build a separate hydro turbine for each hydroelectric power plant further complicates this process. The construction of large-scale hydroelectric power plants is also environmentally harmful. The construction of such facilities leads to a change in the landscape of the area, turning a very large area into a swamp. It also causes great harm to the flora and fauna of the area [14], [15].

Micro-hydroelectric power plants are most useful in areas far from power supply centers, in areas with frequent power outages, and in areas without power lines. Such places may include farm buildings in mountainous areas, small villages, and a few cottage complexes. The capacity of such micro-hydroelectric power plants is selected depending on the power consumption of electricity consumers. The capacity of micro-hydroelectric power plants ranges from several tens of kilowatts to hundreds of kilowatts. Since the consumption schedule of electricity consumers varies throughout the day, it is also advisable to have an additional power source. (For example, diesel generators). However, the cost of 1 kW* hour of energy in such diesel generators is 1200-2000 soums [16].

The cost of energy produced from micro hydropower plants depends on factors such as water flow rate (1 m3 / s), annual water flow balance, and river bed slope [17].

Micro-hydroelectric power plants have the following advantages: simplicity and reliability of their design, high quality of the parameters of the generated electricity in dynamic and static modes, full compliance of the frequency and voltage of the generated electricity with the requirements of GOST, complete automation of work, and environmental safety of the constructive and technological solutions of HPP projects. The possibility of compensating for phase asymmetry.

Methods of constructing microhydropower plants: Microhydropower plants are divided into several types according to the construction method.

Micro hydroelectric power plants are constructed by building dams on the steep slope of a river or canal with fast-flowing water. The capacity of these types of micro hydroelectric power plants is much larger than other types of micro hydroelectric power plants. They are mainly built to provide electricity to small residential areas.

Figure 1. View of the Ozan-type micro hydroelectric power plant.

Diversion-type micro hydropower plants. In this case, a portion of the water flow is diverted from the upstream part of the channel to the downstream part through a smaller channel or pipe. A hydro turbine is installed at the end of the pipe or channel.

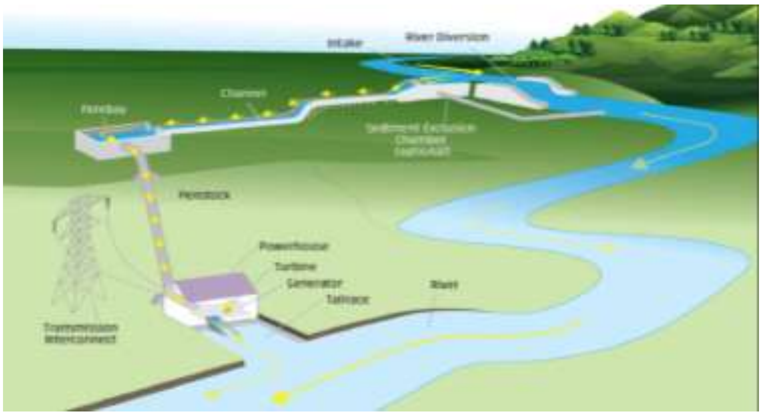

Figure 2. View of a derivational micro hydroelectric power plant.

Simple micro hydroelectric power plants are built on the river itself, without any changes to the river flow. Their capacity is the smallest. Micro hydroelectric power plants usually consist of a hydroturbine (generator), a device for adjusting the output voltage, a series of elements, ballast resistors and protective switches, depending on the type of plant. The most important device in micro hydroelectric power plants is its generator. In addition to converting mechanical energy into electrical energy, its generator also participates in the process of adjusting its parameters. Therefore, it also serves as a controller in such devices. Synchronous machines are often used instead of such generators. The difficulty of excitation in asynchronous generators and the limited ability to adjust the output electrical parameters are the reasons for their limited use.

RESEARCH METHOD

In such equipment, frequency and voltage adjustment is carried out in various ways. Frequency adjustment is carried out by changing the angle of inclination of the working blades or by reducing water consumption. The disadvantage of this method is the long adjustment time (1.5-3 seconds) using ballast resistors. In this case, a ballast resistor is connected to the generator output, and its voltage and frequency are adjusted to the consumers.

Through a generator frequency regulator. It is connected to the blade and generator shaft and helps to maintain the same frequency at the output by giving a constant speed to the generator shaft. Through a machine-valve source device. This device is installed instead of a generator. It differs from other methods in that it produces high-precision voltage and frequency. However, the cost of such devices is very high, so they are rarely used in practice. The most commonly used method today is the autoballast system voltage regulator, which is also economically efficient. Generators (hydroturbines) used in micro hydroelectric power plants are also divided into 2 types.

Active hydroturbines generate power by harnessing the kinetic energy of the water flow as it passes through the turbine nozzle. They are typically used in free-flowing, inclined channels and produce small amounts of power.

RESULT AND DISCUSSION

Reactive hydroturbines. Such hydroturbines operate at the expense of the potential energy of the water flow. They are used in derivative and self-priming microhydropower plants. We can cite as an example of ordinary active generators generators mounted on pulleys. Due to their large overall dimensions and low efficiency, pulley-type hydroturbines are practically not used. Depending on the amount of water flow and the height of the water pressure, hydroturbines are divided into types such as Pelton, Tugro, Banki, Kaplan, Francis. Their average efficiency is 75-80%. In microhydropower plants, the primary energy carrier is the water flow. Factors such as the power of the water flow, water consumption, water pressure, and seasonal stability of the water flow are important in the operation of hydropower plants. However, in many canals and rivers, water flow and pressure fluctuate seasonally. This depends on the climate and the landscape of the area where the river is located. In addition, when designing a micro hydroelectric power plant, the slope of the river, the annual maximum and minimum water consumption are also taken into account. Proper implementation of these calculations leads to a decrease in capital costs and a decrease in energy costs. When choosing a micro hydroelectric power plant, it is taken into account that the flow strength of the river and the energy obtained from the hydroelectric power plant fully meet the energy needs of the consumer. In mountainous areas, derivation-type micro hydroelectric power plants are often used. In this case, a part of the water from the upper part of the river through a small dam is sent to the lower part through a pipe or a specially dug channel. A reactive hydroturbine is installed at the end of the pipe or channel.

Through this pipe, we can increase the energy of the water flow. In this case, when choosing a generator, the diameter of the pipe and the height between the lower and upper parts of the pipe are taken into account. The pipes of micro hydroelectric power plants can be made of steel, rubber, concrete or other hard materials. The choice of material and its cost depend on the terrain of the area where the micro hydropower plants will be located.

In mountainous areas, the location of the land surface, the high slope of local rivers, or the presence of slopes in certain parts of even flat-flowing rivers, increases the potential for the use of micro-hydroelectric power plants. If local conditions allow a water head of less than 1 m, the construction of micro-hydroelectric power plants in such areas would be ineffective.

The water flow in rivers varies seasonally. Therefore, when studying the characteristics of local water flow of micro-hydroelectric power plants, the minimum water flow during the dry season is also taken into account. Another important factor is the freezing of rivers. That is, the duration of this freezing period also affects the power of micro-hydroelectric power plants. Even a slight change in the river flow can lead to a change in the quality of water and the way of life of surrounding wildlife. Therefore, when constructing micro-hydroelectric power plants, it is advisable to use no more than 10% of the total river water flow. The location of the plant plays a significant role in the technical and economic situation of constructing micro-hydroelectric power plants.

They are: Average slope of the river. H (m), average water flow. Q (m^3/s), average water flow velocity. v (m / s), annual flow duration (hours). From these factors, it is possible to determine the approximate capacity of the plant and the amount of electricity generated during the year. For example, the pumping capacity of a micro-hydroelectric power plant depends on the total pressure of the water flow. T is the head pressure - the distance between the upper and lower parts of the turbine or channel. In addition, there is the concept of working pressure, which is equal to the total pressure minus the hydraulic pressure. We can use the total pressure to determine only the approximate capacity of a hydroelectric power plant. However, to determine its exact capacity, we need to determine the working pressure.

$$H = H_{to`la} - h_{tre} - h_{qo`sh} \quad (2)$$

Here h_{tre} is the loss in the trenia, h_{double} is the loss in the addition or valves, buffering, and also in the bending of the pipe.

The loss in traction is found by the following formula.

$$h = J * L \text{ m.} \quad (3)$$

Here J is the hydraulic gradient. L is the length of the pipe.

This formula is used to determine the hydraulic gradient

$$J = a * V^m * D^n \quad (4)$$

Here V is the flow velocity (m/s), D is the pipe diameter. (m). a, n, m are coefficients depending on the material from which the pipe is made. For example, for steel.

Table 1. Material steel pipe.

Material name	A	N	m
Steel pipe	0.885	1.8	1.17

Trumpet conductive micro In hydroelectric power plants train loss determination for Lesson Weisbach from the equation use recommendation is being done .

$$h_{tr} = f * \frac{L}{4R} * \frac{V^2}{2g}, m \qquad (5)$$

On the ground, R is the radius of the pipe. V is the average velocity of the flow. f is a dimensionless coefficient (it depends on the smoothness of the pipe surface)

The additional loss is found as follows.

$$h_{qo`sh} = E_x \cdot \frac{V^2}{2g} (6)$$

Here E_x is a coefficient depending on the pipe curvature. It is usually taken from the data.

As we know, micro hydropower plants were divided into 2 types. Derivative and free-flowing micro hydropower plants. We have already familiarized ourselves with the calculation of derivative-type micro hydropower plants. Now we will get acquainted with the calculation of hydropower plants that are freely installed in the stream without any other hydraulic engineering measures.

The power of a water flow is characterized by the water consumption of this flow and its speed. The cross-sectional area of the river flow and the slope of the river bed are also taken into account. The amount of energy obtained from a micro hydroelectric turbine built on the free flow of water depends on the following equations.

P = 0.09 8 - Q H (7)

n = Q S g H (8)

Q = m/. ² v/4 (9)

N_{oqim}= πdS · v ³ / η · 8(10)

Here P- power (kW), Q - water flow (m3/s), H - full hydrostatic pressure (m), n-rotation frequency of the working turbine wheel (rpm) N flow · full power of the water flow, S - cross-sectional area of the water flow, (m ²) g- 9.8 - acceleration of free fall, d-diameter of the wheel, (m) V_{in}, V_{out} - velocities of water at impact and exit from the wheel, (m/sec) taking into account the full power of the flow H.

$$P_{to`la} = p \cdot q \left[gH + \frac{v_{kir}^2 - v_{chiq}^2}{2} \right] (11)$$

Micro hydropower capacity, taking into account the turbine capacity.

$$P = 0{,}098 \cdot P_{to`la} \eta \ (12)$$

For example, a micro hydroelectric power plant built on a water flow with d = 2m, v = 5m/s, and T = 0.8 can produce 2 kW of energy. It should also be taken into account that a certain amount of energy is also lost in the line from the generator to the consumer.

Usually, when the water flow (Q) and pressure (H) are sufficient, we also pay attention to the material from which the hydropower plants are made and its strength. In each case, each of the components provides different powers. For example, if the canal or river where we want to build a micro hydropower plant has Q = 3m ^{3} /s, H = 1.5m, V $_{in}$ = 6 m/s, V $_{out}$ = 2 m/s, η= 0.8, we find the electrical power generated by the micro hydropower generator built there.

$$P = \eta \cdot \rho \cdot Q \left[Hg + \frac{v_{kir}^2 - v_{chiq}^2}{2} \right] = 0{,}8 * 1000 * 3(1{,}5 * 9{,}8 + \frac{6^2 - 2^2}{2} = 73{,}7\ kVt$$

So, under such conditions, we can provide an average of 7 households with electricity. In real turbines, the main parameters H, Q, P, n are known. D is the maximum diameter of the 1st turbine wheel. Micro hydropower plants have 2 turbines.

$$\frac{n_a}{n_b} = \frac{D_{1b} \cdot \sqrt{H_a}}{D_{1a} \cdot \sqrt{H_b}} \quad (13)$$

Here, a and b are quantities related to the speed of water passing through the turbine. The ratios of water consumption of the two turbines are written as follows:

$$\frac{Q_a}{Q_B} = \frac{D_{1b} \cdot \sqrt{H_a}}{D_{1a} \cdot \sqrt{H_b}} \quad (14)$$

The efficiency of the two turbines.

$$E_\eta = \sqrt{\frac{\eta_{tru}}{\eta_{to`la}}} (15)$$

For example, if two turbines have the same power, one of which is H=1 m, D=1 m, then the number of revolutions $n = \frac{60u}{\pi D_1}$will be equal. The velocity of the flow $\varphi\sqrt{2gH}$will be v=. $\varphi -$ the viscosity of the flow.

Formula for the relationship between the potential and kinetic energy of the fluid and the turbine parameters.

$$E_{ish} = \frac{P}{\gamma} + \frac{\alpha V^2}{2g} \ (16)$$

$$n_1^l = \frac{nD_1}{\sqrt{H}} \ (17)$$

$$Q_1^l = \frac{Q}{D_1^2 \ \sqrt{H}} \ (18)$$

$$N_l^1 = \frac{N}{D_1^2 \quad H\sqrt{H}} \ (19)$$

Here E $_{work}$ is the energy of the flow work, n_1^l- the turbine frequency. Q_1^l- the water flow rate through the turbine. N_1^l- the turbine power according to the first approximation.

The rotational frequency of many turbines can also be related to the horsepower of the generator.

$$n_s = \frac{n_1\sqrt{N_{ot.k}}}{H\sqrt[4]{H}} \ (20)$$

Calculations show that for individual consumers it is sufficient to build micro-hydroelectric power plants with a capacity of 5.5-7.5 kW. To obtain such energy, the flow velocity must be at least 1.0-1.5 m/s, or faster to obtain greater power.

It would be appropriate to use the energy of small rivers and canals, large streams, for individual consumers, small settlements, agricultural work, as well as in mountainous areas far from power lines. This would increase the possibility of obtaining more energy at lower costs.

CONCLUSION

Fundamental Findings : Hydropower utilizes both kinetic and potential energy from water flow to generate electricity. The efficiency of hydroelectric power plants is significantly higher than that of thermal power plants, reaching up to 80%. The energy output of hydroelectric plants depends on factors such as water flow rate, pressure head, and turbine efficiency. Large-capacity hydroelectric power plants require extensive infrastructure and can have considerable environmental impacts, while micro-hydropower plants provide sustainable energy solutions for remote areas with minimal ecological disturbance. **Implications :** The application of hydropower, particularly micro-hydropower plants, offers a sustainable alternative to conventional energy sources, especially in off-grid locations. Their environmental footprint is lower compared to large-scale hydroelectric plants, and they provide reliable electricity to small communities. However, seasonal water fluctuations and terrain limitations must be considered to ensure consistent energy generation. The development of efficient hydropower technologies can contribute to reducing reliance on fossil fuels and enhancing energy security. **Limitations :** Despite their advantages, hydropower plants face several limitations, including dependency on water availability, environmental impacts, and high initial investment costs. Large-scale projects alter natural landscapes and ecosystems, while micro-hydropower plants may experience power inconsistencies due to seasonal water level variations. Additionally, complex engineering requirements and maintenance challenges may restrict their widespread adoption in certain regions. **Future Research :** Future research should focus on improving the efficiency of hydropower technologies, particularly in micro-hydropower applications. Innovations in turbine design, automation, and hybrid energy systems integrating solar or wind power could enhance performance. Additionally, research on mitigating environmental impacts and optimizing site selection criteria will be crucial in promoting sustainable hydropower development globally.

REFERENCES

[1] T. Nasirov, A. Vasykov, J. Byari, L. Zavyalova, and P. Pozychanyuk, *In Uzbekistan Again Renewable Energy Development Prospects*. Tashkent, Uzbekistan: Uzbekistan, 2007, p. 92.

[2] K. R. Allaev, “The potential for the efficiency of alternative energy sources in the Republic of Uzbekistan,” *Problems of Energy and Resource Saving*, no. 4, Tashkent, 2015.

[3] P. P. Bezrukikh, *Wind Energy*. Moscow, Russia: Enerpgiya, 2010, p. 320.

[4] “Assessment of the Development of Wind Energy Potential of the Republic of Uzbekistan - Mesoscale Modeling and Site Evaluation,” Summary Information, Tashkent, Uzbekistan, 2016, p. 4.

[5] *Materials of the Second National Conference on the Development of Wind Energy Potential of the Republic of Uzbekistan*, Tashkent, Uzbekistan, 2016, p. 6.

[6] J. X. Suvonov and S. A. O'lmasov, "Impact of Solar Power Plants on the Electrical Energy System," *Mechanics and Technology*, vol. 1, no. 8 (Special Issue), pp. 265–269, 2024.

[7] S. A. O'lmasov, J. X. Suvonov, and S. A. Asqarjonov, "Innovative Methods of Cooling Solar Panels in Hot Climate Conditions," *Construction and Education*, vol. 3, pp. 239–243, 2024.

[8] J. X. Suvonov, "Experiential Learning: Education Through Experience," *Economics and Society*, vol. 12, no. 115-2, pp. 418–420, 2023.

[9] J. X. Suvonov, "Socratic Method in Modern Education: Encouraging Analytical Thinking," *Economics and Society*, vol. 12, no. 115-2, pp. 421–423, 2023.

[10] J. X. Suvonov and M. Jamoliddinov, "Concentration of Solar Radiation," *Journal of New Century Innovations*, vol. 67, no. 3, pp. 91–95, 2024. [Online]. Available: https://scientific-jl.org/new/article/view/7212.

[11] J. X. Suvonov and Q. Abdumalikov, "Study of Wind Energy Activity in the Mountainous and Foothill Regions of the Republic of Uzbekistan," *Journal of New Century Innovations*, vol. 67, no. 3, pp. 96–104, 2024. [Online]. Available: https://scientific-jl.org/new/article/view/7213.

[12] J. X. Suvonov and Q. Abdumalikov, "Construction and Characteristics of Wind Energy Equipment," *Journal of New Century Innovations*, vol. 67, no. 3, pp. 105–111, 2024. [Online]. Available: https://scientific-jl.org/new/article/view/7214.

[13] G. S. G. Soliyeva, N. Z. N. Zokirova, D. M. D. Mahmudova, J. S. J. Suvonov, D. A. D. Abdusattorov, and R. A. R. Anvarjonova, "Approximation of Spline Function," *Universal International Scientific Journal*, vol. 1, no. 12, pp. 270–273, 2024.

[14] J. X. Suvonov and S. A. O'lmasov, "Impact of Solar Power Plants on the Electrical Energy System," *Mechanics and Technology*, vol. 1, no. 8 (Special Issue), pp. 265–269, 2024.

[15] S. A. O'lmasov, J. X. Suvonov, and S. A. Asqarjonov, "Innovative Methods of Cooling Solar Panels in Hot Climate Conditions," *Construction and Education*, vol. 3, pp. 239–243, 2024.

[16] J. X. Suvonov, "Experiential Learning: Education Through Experience," *Economics and Society*, vol. 12, no. 115-2, pp. 418–420, 2023.

[17] J. X. Suvonov, "Socratic Method in Modern Education: Encouraging Analytical Thinking," *Economics and Society*, vol. 12, no. 115-2, pp. 421–423, 2023.

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