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DETERMINATION OF ENERGETIC PARAMETERS OF GARLAND MOBILE MICRO-HYDRO POWER PLANT FOR MOUNTAIN AREAS

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ABSTRACT

In this article, energetic parameters of garland micro hydroelectric power stations were organized and analyzed. In this case, the output energetic parameters of the device were studied by changing the number and size of the working surface of the garland micro hydroelectric power station blades. As an output energetic parameter, the number of rotations of the blades at different speeds of water flow, the generated torque and the corresponding power generated in the electric generator, as well as the effect of the diameter and length of the blades on the energy efficiency indicators were studied. According to the preliminary results of the basis of the composition of the device, the option of making the main structural components from polymer materials was chosen. An increase in the water flow rate requires changing the operating modes of the electric generator, and this requires the selection of a special hydro generator. The garland micro-hydroelectric power plant under construction has a mobile structure, which creates opportunities for short-term transportation and commissioning to areas where electricity is required.

Key words: Garland micro hydroelectric power plant design, kinetic energy, turbine rotation monent, polimer hydro turbines, hydrogenerator.

JEL Classification Codes: Q42, Y40

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Original Article

INTRODUCTION

Experiences of developed countries in the use of garland micro-hydroelectric power plants cannot be directly applied to the conditions of Uzbekistan. Because in the conditions of Uzbekistan, there is a significant difference in the terrain of the foothills, seasonal water reserves, and even the slope indicators of some areas. Therefore, it is advisable to take into account the uniqueness of the region when introducing such technologies.

Namangan region is considered one of the mountainous regions of the Republic of Uzbekistan. The area is 7.44 thousand km². The population is 2931.5 thousand people. One of the big rivers, Syrdarya, flows through Namangan. In addition, the energy potential of streams flowing from the mountains is considered very high. It is appropriate to use traditional sources of energy for providing electricity in mountain areas located far from the center.

Chodaksoy is a stream in Namangan (province) Pop district. It starts from the side of the Kurama ridge. It flows into the Syrdarya in the territory of Tepakorgan village. Its length is 76 km, basin area is 566 km², average height is 2370 m. Water consumption is 3.72 m³/sec., average 7.24 m³/sec during the growing season. It is full of snow and glaciers. Chodaksoy is used to irrigate cultivated fields in Pop district.

a) b)

Figure 1: a) Location of Namangan Region in the Territory of the Republic of Uzbekistan, B) Chodak Stream.

Table 1

Years	Long-Term Data On Chodak Stream Water Consumption, M^3/S												
	Januar	Februa	March	April	May	June	July	Augus	Septem	Octobe	Nove	Decem	Avera
2000	0,3	0,3	0,5	20	10	8	0,4	0,2	0,2	0,3	0,25	0,35	3,40
2001	0,32	0,32	0,52	20,02	10,02	8,02	0,42	0,22	0,22	0,32	0,27	0,37	3,42
2002	0,32	0,32	0,52	20,02	10,02	8,02	0,42	0,22	0,22	0,32	0,27	0,37	3,42
2003	0,33	0,33	0,53	20,03	10,03	8,03	0,43	0,23	0,23	0,33	0,28	0,38	3,43
2004	0,34	0,34	0,54	20,04	10,04	8,04	0,44	0,24	0,24	0,34	0,29	0,39	3,44
2005	0,27	0,27	0,47	19,97	9,97	7,97	0,37	0,17	0,17	0,27	0,22	0,32	3,37
2006	0,28	0,28	0,48	19,98	9,98	7,98	0,38	0,18	0,18	0,28	0,23	0,33	3,38
2007	0,27	0,27	0,47	19,97	9,97	7,97	0,37	0,17	0,17	0,27	0,22	0,32	3,37
2008	0,28	0,28	0,48	19,98	9,98	7,98	0,38	0,18	0,18	0,28	0,23	0,33	3,38
2009	0,34	0,34	0,54	20,04	10,04	8,04	0,44	0,24	0,24	0,34	0,29	0,39	3,44
2010	0,33	0,33	0,53	20,03	10,03	8,03	0,43	0,23	0,23	0,33	0,28	0,38	3,43
2011	0,25	0,25	0,45	19,95	9,95	7,95	0,35	0,15	0,15	0,25	0,2	0,3	3,35
2012	0,23	0,23	0,43	19,93	9,93	7,93	0,33	0,13	0,13	0,23	0,18	0,28	3,33
2013	0,22	0,22	0,42	19,92	9,92	7,92	0,32	0,12	0,12	0,22	0,17	0,27	3,32
2014	0,27	0,27	0,47	19,97	9,97	7,97	0,37	0,17	0,17	0,27	0,22	0,32	3,37
2015	0,23	0,23	0,43	19,93	9,93	7,93	0,33	0,13	0,13	0,23	0,18	0,28	3,33
2016	0,24	0,24	0,44	19,94	9,94	7,94	0,34	0,14	0,14	0,24	0,19	0,29	3,34
2017	0,25	0,25	0,45	19,95	9,95	7,95	0,35	0,15	0,15	0,25	0,2	0,3	3,35
2018	0,27	0,27	0,47	19,97	9,97	7,97	0,37	0,17	0,17	0,27	0,22	0,32	3,37
2019	0,23	0,23	0,43	19,93	9,93	7,93	0,33	0,13	0,13	0,23	0,18	0,28	3,33
2020	0,21	0,21	0,41	19,91	9,91	7,91	0,31	0,11	0,11	0,21	0,16	0,26	3,31
2021	0,2	0,2	0,4	19,9	9,9	7,9	0,3	0,1	0,1	0,2	0,15	0,25	3,30
2022	0,25	0,25	0,45	19,95	9,95	7,95	0,35	0,15	0,15	0,25	0,2	0,3	3,35

The first examples of garland hydroelectric plants were developed in the middle of the 20th century. However, turbine blades are made of heavy metals. In this case, a lot of moment of inertia is required. Polymer materials are lighter and more durable. Garland micro-hydroelectric power plants operating in free streams work without special devices for directing the water flow and without special hydrotechnical structures (dams).

In mountain and sub-mountain regions, the recommended garland micro-hydroelectric power plant is used to generate electricity from the kinetic energy of rivers and streams with high water velocity. The blades of this garland micro-hydroelectric plant and their fixing base are made of polymer materials (Figure 2).

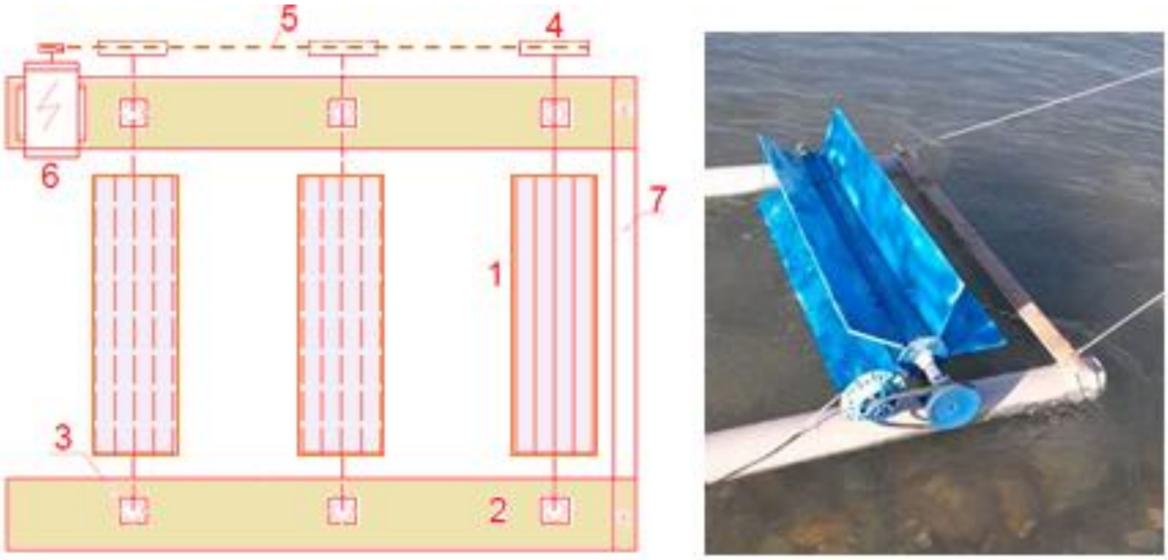


Figure 2: A Floating Garland Micro-Hydroelectric Plant.

In this: 1- turbine; 2-float cylinder; 3-bearings; 4-pulley; 5-belt transmission; 6- hydro generator; 7-Holder.

Methods:

Garland micro-hydroelectric plants do not harm the flora and fauna of the area from the ecological point of view. It can also work in places with a low water level (above 0.4 m) [1].

The efficiency of the Garland micro hydropower plant depends on the following factors:

- To the speed of water flow.
- To the turning angle of the edges of the water blades.
- To the turning angle of the edges of the water sheet.
  - The number of blades of a turbine.
  - Weight of the device.

All this affects the torque of the blades and the number of revolutions.

In this paper, the characteristics of floating garland micro hydroelectric power plant were studied by experimental and computer programs. In this case, the efficiency of the water blade was calculated by changing the water speed, the surface of the blade, the number of blades and the angle of the direction of the water.

GARLAND MICRO HYDROELECTRIC POWER PLANT DESIGN

Light and strong polymer materials were used in its construction so that the device does not rust and sink in water. The structural parts of the garland micro-hydroelectric plant are as follows[2].

- Turbine blades made of polymer material;
- A float cylinders;
- Iron strap for attaching the blades of the turbine to the horizontal shaft;

- Support bearings;
- Pulley;
- Belt transmision;
- Hydro generator;
- A rope holding a garland micro-hydroelectric plant.

Table 2: Dimensions of the Garland Microhydroelectric Plant Turbine [3]

№	Parameters	O'lchamlari (mm)
1	Outer diameter	150….550
2	Internal diameter	100
3	The height of the blades	100….500
4	The length of the blades	L=1000
5	The thickness of the blades	4
6	Number of blades	N_1=5…10
7	Pulley diameter	100

Theoretical calculations:

Garland micro hydroelectric power parameters testing station:

It is possible to describe the power of water acting on the blades of the micro-hydroelectric power station:

$$F = \frac{1}{2} \cdot \rho \cdot S \cdot v^2, \text{(Newton)} \qquad (1)$$

Taking into account that the blades of a turbine is rectangular, its surface is as follows:

$$S = h \cdot L, [m^2] \qquad (2)$$

In this: h-the height of the blades [m];

L-the length of the blades [m];

ρ-density of water 1000 [kg/m^3];

v-water flow rate [m/s].

The torque is equal to:

$$M = F \cdot (R - h/2), (N \cdot m) \qquad (3)$$

R- turbine radius.

The total torque of floating turbines is found as follows:

$$M_u = \sum_{i=1}^{N} M = \sum_{i=1}^{N} F \cdot (R - h/2), (N \cdot m) \quad (4)$$

In this: N-number of turbine

i-number of turbine blades.

The output power from the turbines of micro hydro power plant is calculated as follows:

$$P_o = N \cdot P_t \cdot \eta_t \cdot \eta_m \cdot \eta_g, \text{ (W)} \quad (5)$$

In this: η_t- useful efficiency of the turbine (0,23-0,33),

η_m- mechanical useful work coefficient (0,7-0,85),

η_g- useful efficiency of generator (0,9-0,95)

On the other hand, the output power is:

$$P_o = \sum M \cdot \omega, \text{ (W)} \quad (6)$$

$$\omega = \frac{v_t}{R}, \text{ (radian/sec)} \quad (7)$$

In this: ω- turbine angular velocity (rad/sek);

v_t- tangential velocity (m/s).

$$v_t = v \cdot \cos\varphi, \quad (8)$$

φ- the angle between the turbine blades.

The value obtained from the turbine is determined as follows [4].

$$P_t = \frac{1}{2} \cdot \rho \cdot S \cdot v^3, \text{ [W]} \quad (9)$$

In this case, the useful work coefficient of the turbine is equal to the following:

$$\eta_t = \frac{2 \cdot M_u \cdot \cos\varphi}{R \cdot \rho \cdot S \cdot v^2}, \quad (10)$$

The efficiency of the turbine depends on the part of the turbine blades immersed in water and the speed of the water.

Result: We considered the dependences of the energetic parameters of the garland mobile micro-hydroelectric power plant, which converts the kinetic energy of water into electrical energy. Research shows that the output power depends on the speed of water, the contact surface of turbine blades with water, the number of turbine blades and the angle of impact of water on the blade. In order to improve energy efficiency, we have increased the optimal range of water speed, the height of the blades, the number of blades and turbines accordingly.

Figure 3 shows the change in output power when the speed of water increases. Here, when the surface of the submerged part is equal to 0,1 m^2, the efficiency is 25%. When considering the number of blades, *i*=5, transmission efficiency is 85%, and generator efficiency is 95%.

Figure 4 shows the effect of increasing the surface area of the blades on the output power. In this case, the surface of impact was increased to 0.5 m^2, the speed of water was v=2 m/s.

In Figure 5, when we increase the surface of the turbine blades, we can see the effect on the efficiency of the turbine. The speed of water flow is v=2 m/s, the number of blades is *i*=5, and the surface of the blade is 0,15 m^2.

Figure 6 shows the relationship between the number of blades and the number of revolutions. In the case when the water speed is v=2 m/s, R=0.2 m.

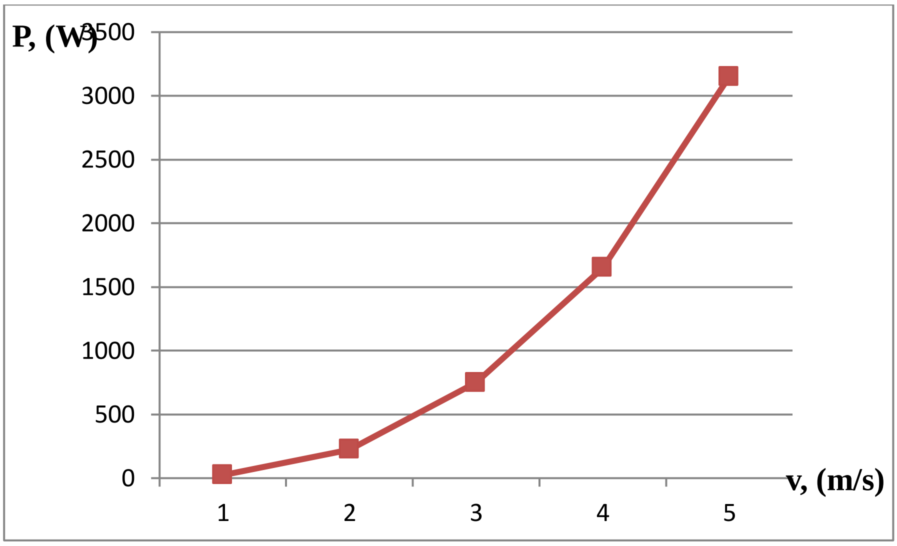


Figure 3.

Dependence of output power, water flow rate. The submerged part of the wind turbine is h=10 cm, the number of wind turbines is *i*=5, the number of turbine is N=3, when the turbine efficiency is 25%, the transmission efficiency is 85%, and the generator efficiency is 95%.

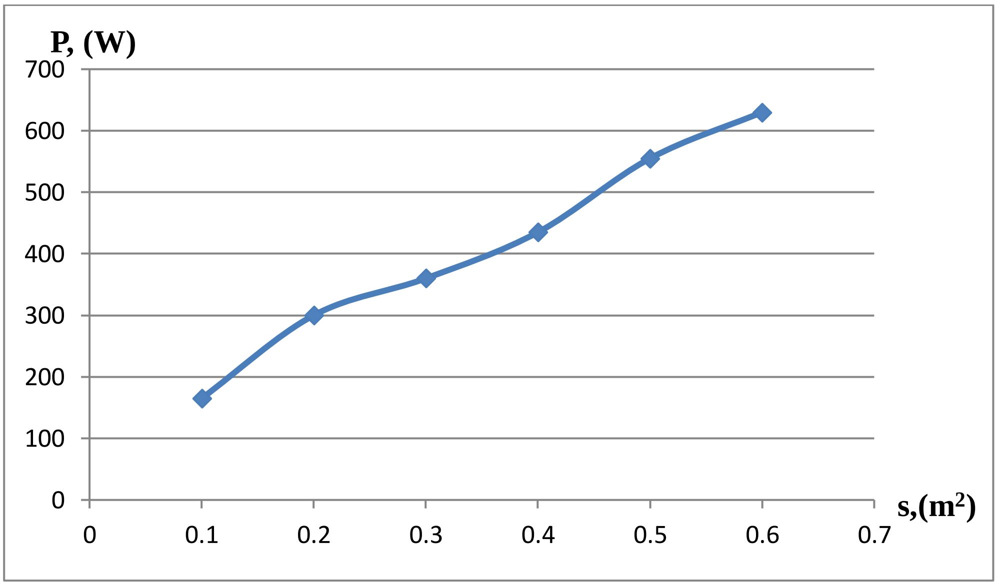


Figure 4.

Dependence of the output power on the part of the blade immersed in water. When the water flow speed is v=2 m/s, the number of blades is *i*=5, the number of turbine is N=3, the efficiency of the turbine is 25%, that of the gears is

85%, and the efficiency of the generator is 95%.

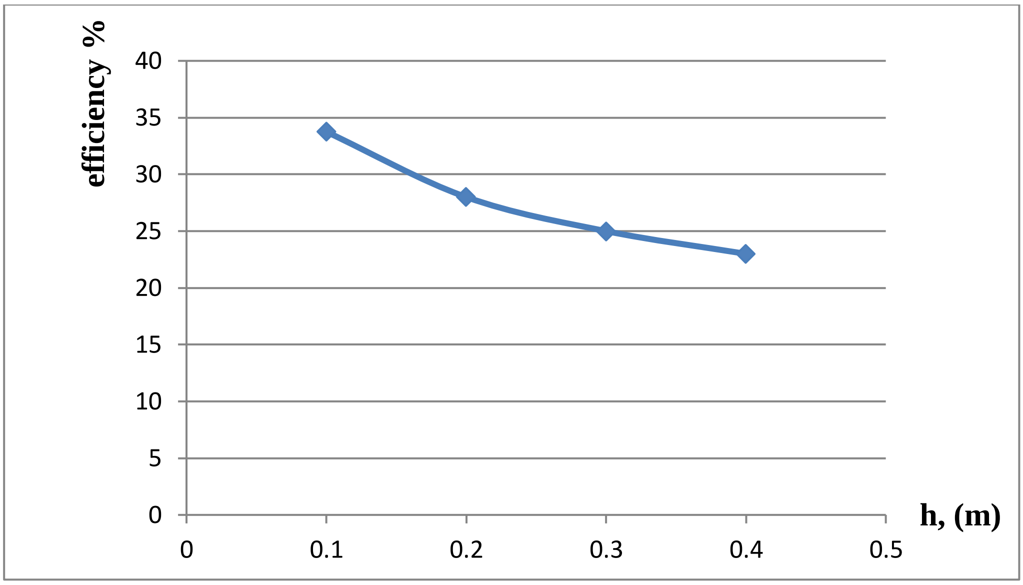


Figure 5.

Dependence of the efficiency coefficient of the turbine on the water-immersed part of the blade. When the water flow speed is v=2 m/s, and the number of blades is *i*=5.

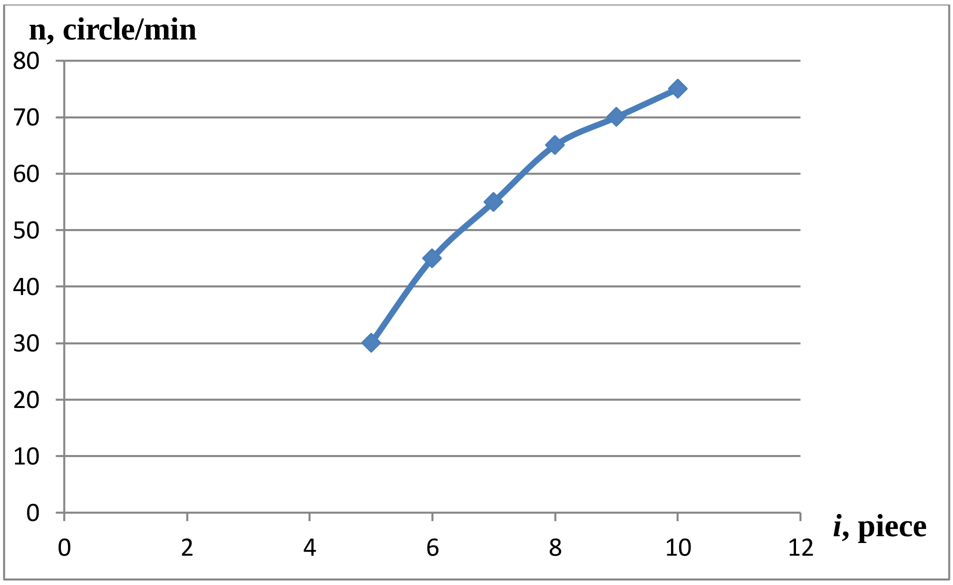


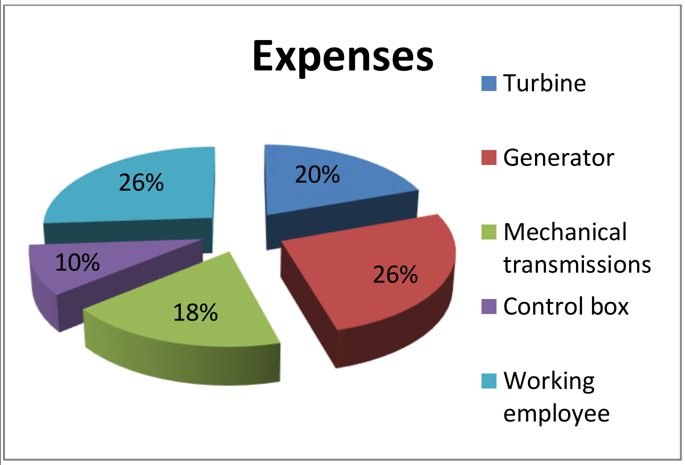
Figure 6: 6-rasm

Dependence of the number of revolutions on the number of turbine blades. When the water flow speed is v=2 m/s, and the turbine radius is R=0,2 m.

Economic part

Capital costs of micro hydro power plant (physical model):

Turbine	73,5 $
Generator	98 $
Mechanical transmissions	69 $
Control box	36 $
Working employee	98 $
Total capital cost	375,5 $
Production capacity	0,5 kW
Comparative price	751 dollar/kW



The electric power produced by the micro hydro power station in one year is as follows:

$$W_{year} = P \cdot t_{w.t} = 0{,}5 \cdot 8760 = 4380\ kW \cdot h$$

In this case, $t_{w.t}$=8760 hours, the operating time of the micro hydro power station.

Determining the annual economic indicator:

$$T_{year} = W_{year} \cdot C_{g.e} = 4380 \cdot 3 = 128{,}7\ dollar$$

In this case, $C_{g.e} = 3\ sent$ (price of 1 kW·h of green energy)

Determining the payback period of mikro hydro power station:

$$t_d = {}^{T_{cap}}\!/_{T_{year}} = 375{,}5/128{,}7 = 2{,}9\ year$$

CONCLUSIONS

In this article, the preliminary design and calculations of the garland mobile micro-hydroelectric plant were carried out. According to the preliminary results, it was planned to make the main structural part of the device from polymer materials. In this case, the number of turbines is divided into N= [1-3] units and connected to one generator. It was studied that the surface of the water blade is S= [0.1-0.5] m^2 and the number of turbine blades is i= [5-10]. It is necessary to choose a special hydrogenerator if the water speed is in the range v= [1-5] m/s. It is required to use details with stainless and hermetic construction intended for working in water. The mobile design of this device requires that it be convenient, safe and reliable in terms of transportation. The length, height, number of rows and the distance between them are optimized from the point of view of energy efficiency.

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