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Design of a Gravity Water Vortex Power Plant for Discharge Pools of Pumping Stations

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ABSTRACT: The demand for energy in the world is increasing day by day and this is causing the problem of climate change. Maximizing the use of renewable energy sources is required to address declining energy reserves and environmental challenges. In this research paper, the practical design of a gravity water vortex power plant and ways to increase the work efficiency are presented, making optimal use of the hydropower potential of the pumping stations discharge pools. The object of the study was the Fergana pumping stations under the Syrdarya-Sokh Irrigation Systems Basin Department and the Faizabad pumping station under the Energy Department on the hydropower potential of the discharge pool. Gravity water vortex power plant is a new modern green technology as an alternative or renewable energy source. The advantage of this method of generating electricity is that it has the ability to generate electricity at low pressure, ie from 0.7 meters above sea level.

KEYWORDS: renewable energy basin parameter, depth discharge, very low head turbine, gravitational vortex turbine.

I. INTRODUCTION

Today, the development of a society is determined by its energy supply. However, the increasing consumption of energy, as well as the use of fossil fuels for its production, leads to global pollution of the environment and, as a result, poses a serious threat to human life. Therefore, one of the current issues in energy is the use of environmentally friendly, non-renewable energy sources [6]. Efficient use of hydropower potential of the country, formation of a unified system of hydropower management, gradual increase in the share of renewable hydropower resources in electricity generation, organization of new environmentally friendly energy generating facilities, technical and technological re-equipment of existing hydropower plants, PQ-2947 of the President of the Republic of Uzbekistan dated May 2, 2017 on measures for further development of hydropower in order to attract foreign investment in the development of hydropower and on this basis to more fully meet the needs of enterprises and the population in electricity It is important to implement innovative ideas on the basis of the decision [5].

The result of this research is to improve the design parameters and increase the efficiency of the existing low-pressure water gravity micro-hydropower plant. This method of power generation was first patented and put into practice in 2003 by the Austrian inventor Franz Tsotleterer, in which part of the water flowing from a river or stream is directed into a concrete cylinder [6]. The water falls into the cylinder and forms a spiral gravitational vortex, and a turbine mounted vertically in the middle moves along with the water. The efficiency of this gravitational vortex micro hydroelectric power plant will depend on many factors such as the parameters of the basin, the design of the vortex pool and the construction of the fins. By eliminating the above factors, the task is to generate electricity while ensuring the optimal operating mode of the station. Just as hydroelectric power plants have advantages over steam and fuel-fired power plants, micro-hydroelectric power plants also have certain advantages over other energy sources. These advantages include:

Microhydroelectric power plants require low flow rates and low pressures to generate electricity.

There is no need for a reservoir or a large basin, which in turn reduces the problem of the level of danger of the dam in place, so the facility can be installed close to the consumer.

Since no large dams and reservoirs are required in the construction of the facility, the initial capital expenditure is reduced.

Stations of this type operate along river, or stream streams, so they are harmless to the basin landscape and aquatic ecosystems.

In regions with hydropower potential, it serves as the most economical system due to the construction and maintenance of facilities in the autonomous state.

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These types of power plants will be able to solve the energy shortage in the system as an off-grid solution and supply electricity.

Costs and energy losses associated with power transmission lines are minimal because the stations are located close to the point of consumption [2-3].

A gravitational vortex microhydroelectric power station with the above advantages is green technology as an alternative or renewable energy source. This method of power generation was first patented and put into practice in 2003 by the Austrian inventor Franz Tsotleterer, in which part of the water flowing from a river or stream is directed into a concrete cylinder [6]. The water falls into the cylinder and forms a spiral gravitational vortex, and a turbine mounted vertically in the middle moves along with the water. A rotating turbine along with a gravitational vortex is attached to an electric generator, and the electric generator converts mechanical rotational motion into electrical energy. The efficiency of this gravitational vortex micro-hydropower plant will depend on many factors such as the parameters of the basin, the design of the vortex pool and the design of the fins. Figure 1 a) below shows a schematic diagram of a gravitational vortex hydroelectric power plant.

All microhydroelectric power plants have certain advantages over each other. However, gravitational vortex microhydroelectric power plants have the following advantages over all other types:

Because the station operates at low angular speeds, it does not interrupt the flow and does not damage the aquatic ecosystem.

The installation of a hydroelectric power plant is easy and the return on investment starts after a very short period of time, i.e. by itself.

It significantly increases the flow rate of water in a cylindrical reservoir without any external influences due to the gravitational vortex.

The efficiency of power generation is high because water affects all the wings at the same time.

There is no need for dams and dykes as the construction is installed along the stream and river flow direction.

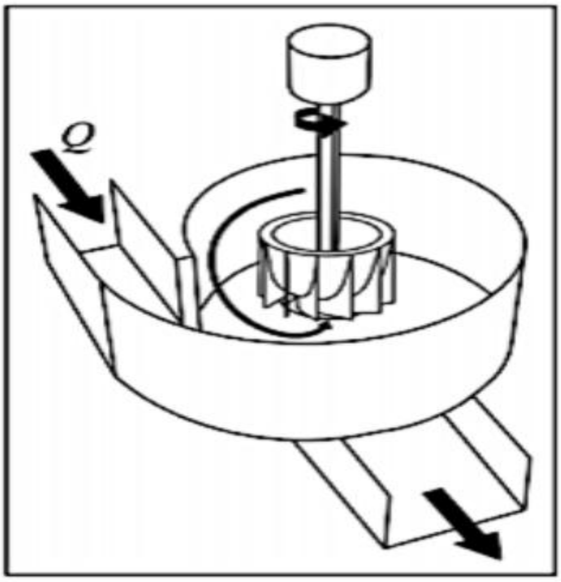
Costs and energy losses associated with power transmission lines will be minimal because the stations are located close to the point of consumption.

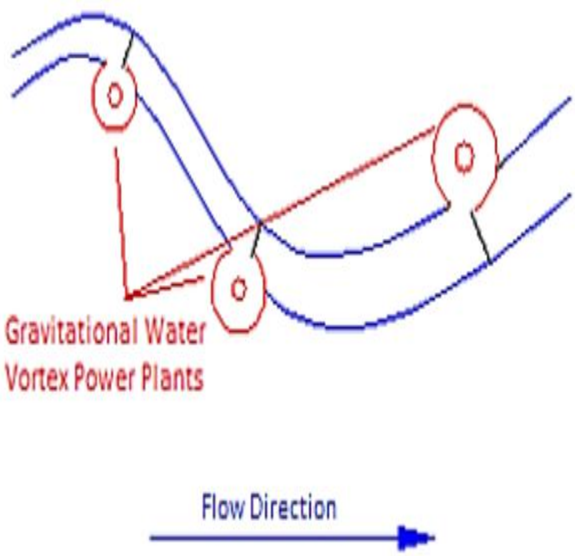
Maintenance and operating costs are low because the construction is not complicated.

Parts can be manufactured by local manufacturers.

It can be used at low pressures (0.7m - 3m).

It is possible to install several turbines of the same capacity in a cascade along the water flow, which can be systematically designed as shown in Figure 1, b) [4-5].





a) b)

Fig. 1. Gravitational vortex microhydroelectric power station. a) schematic diagram, b) cascade structural diagram.

The efficiency of this gravitational vortex micro hydroelectric power plant will depend on many factors such as the parameters of the basin, the design of the vortex pool and the construction of the fins. In order to achieve

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maximum efficiency, it is necessary to optimally design the shape of the micro-hydroelectric power plant and the profile of the blade accordingly. In addition, experiments have shown that the efficiency of aluminum blades is higher than that of steel blades, and that the optimal value of blades is 0.65 to 0.75 percent of the height of the blades. Pool design is an important parameter to effectively create a vortex inside the basin. The vortex is directly related to the tangential and radial velocity of the water in the basin, the width and height of the water inlet corridor, and the initial velocity of water at the inlet.

II. METHODOLOGY

A. Microhydroelectric power plants

Microhydroelectric power plants are small-scale hydropower systems that generate power from 5 кВт to 100 кВт. In general, micro-hydropower systems do not require large dams or reservoirs, but are characterized by the ability to effectively use the hydropower potential of rivers, canals, streams and irrigation networks[1]. In practice, active and jet hydraulic turbines have been used depending on the water pressure. However, the high demand for energy requires the use of other types of low-pressure hydraulic turbines. Figure 3 below shows the classification of a micro-hydroelectric power plant turbine.

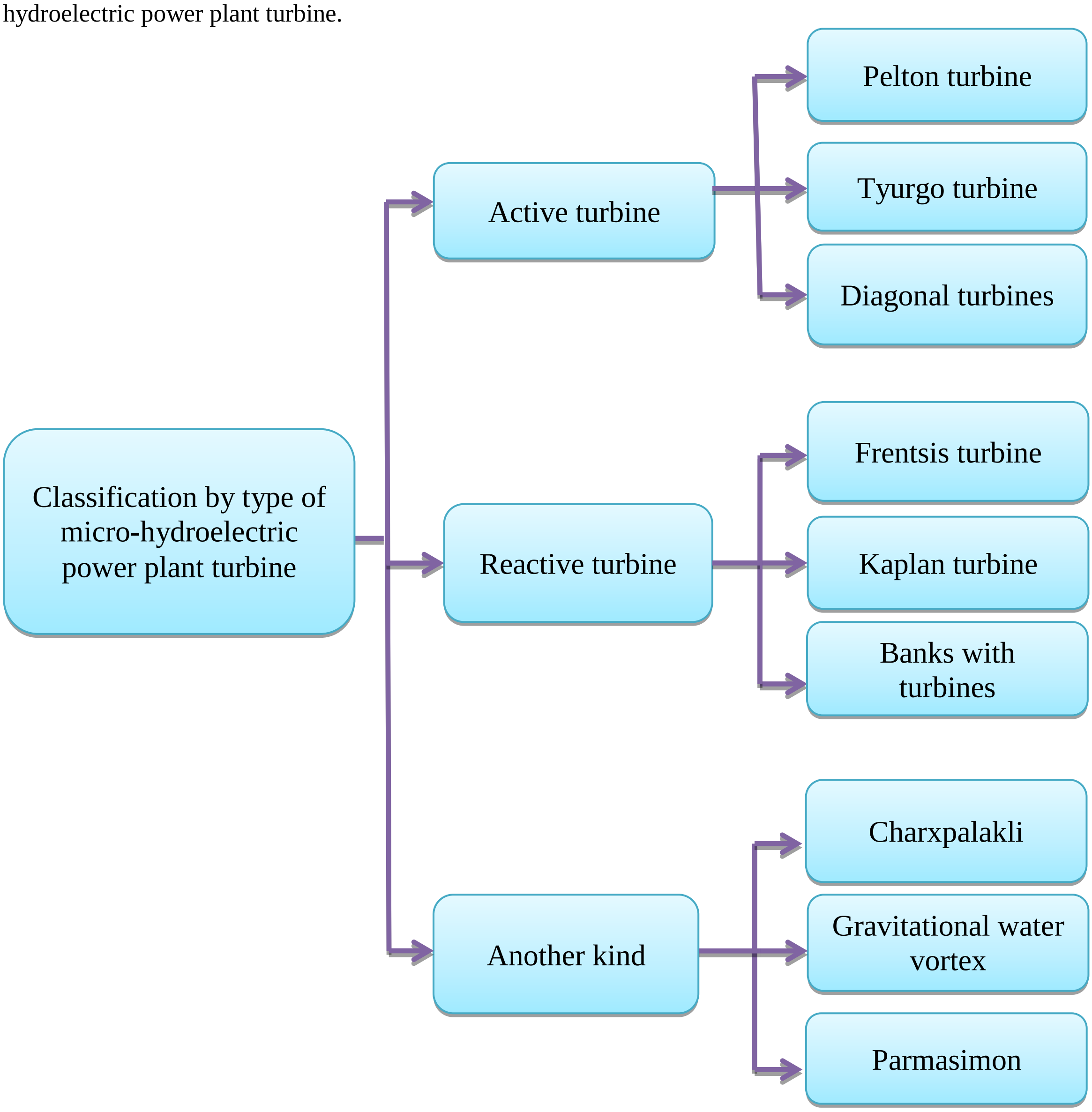

Fig. 2. Classification of micro-hydroelectric power plant turbine

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A gravitational vortex microhydroelectric power station with the above advantages is green technology as an alternative or renewable energy source.

B. Location of the research object.

This study was conducted on the hydropower potential of the Fergana pumping stations under the Syrdarya-Sokh Irrigation Systems Basin Department and the Faizabad pumping station under the Energy Department. The pumping station will be supplied with water through the Akhunbabayev canal. Irrigation systems in the eastern part of the Fergana region are supplied by the canal's water resources. Figure 4 shows the location of the Faizabad pumping station. Table 1 shows the parameters of this channel.

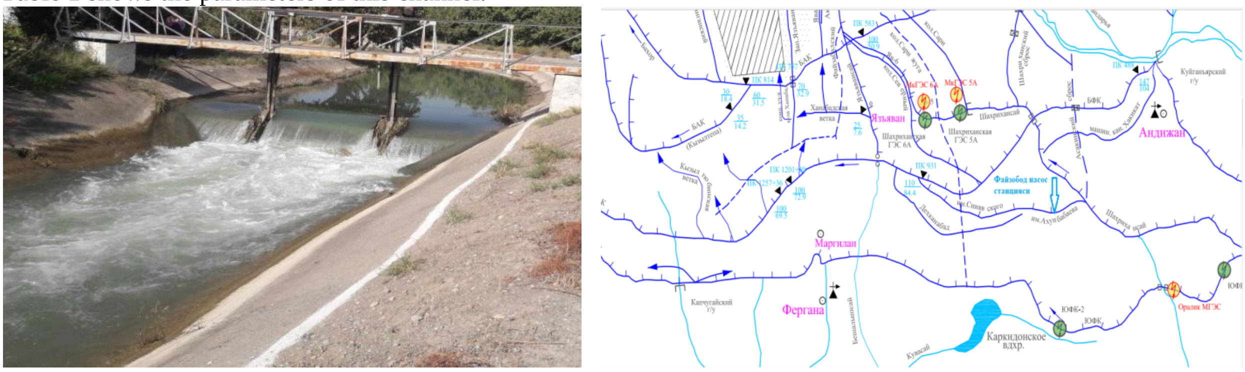

Fig. 3. Location of Faizabad pump station.

Table-1.
Channel parameters according to measurement results

Parameters	Value	Unit of measurement
The width of the channel	6	м
The depth of the channel	3	м
The height of the canal dam	1.3	м
Effective height	1.7	м
Average water consumption	1.92	$м^3/с$

C. Calculation of Electric Power

It is envisaged to generate electricity using the effective volume of water flowing over the discharge pool dam by directing it to the cylindrical basin of a gravitational vortex microhydroelectric power plant. Turbine power is determined using fluid mechanics equations according to the dimensions of the components. The electric power generated by a gravitational vortex hydroelectric power plant in watts (V) is calculated using the formula given in (P), (1).

$$P_{МГЭС} = \rho * g * Q * H_{сам} * \eta_{МГЭС} \qquad (1)$$

Here: ρ =1000 $кг/м^3$ - specific gravity of water, g =9.8 $м/с^2$ – free fall acceleration, $H_{сам}$ - effective height of water, Q- average water consumption $м^3/сек$ $\eta_{МГЭС}$ - efficiency of a hydro-electric power plant with a gravitational vortex [12].

Since the water supply of the Faizabad pumping station is provided through the Akhunbabayev canal and this canal is connected to the irrigation network, the volume of running water is carried out according to a clearly defined schedule. Data on the flow rate of the canal over a period of 3 years was obtained from the database of the Fergana pumping stations and the Energy Department. To verify the accuracy of the data obtained, the water consumption was calculated by multiplying the flow rate (y) by the cross-sectional surface (S) of the channel according to the formula given in expression (2).

$$Q = \vartheta * S \qquad (2)$$

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Here Q is the water consumption (m^3 / s), v is the water flow rate (m / s) and S is the cross-sectional area of the channel (m^2) [11].

III. RESULTS AND DISCUSSIONS

A. Hydropower analysis

Hydropower analysis is the first step in determining the electrical energy potential that can be generated by a gravitational vortex microhydroelectric plant. Data on the flow rate of the canal for 3 years, ie 2019, 2020 and 2021, are taken from the database of Fergana pumping stations and energy department, which will be the basis for determining the average flow rate over months and years. Based on the data obtained, the average monthly water consumption and hydropower capacity are given in Table 1. From the figures given in the table, it can be concluded that the Faizabad pumping station, which is supplied by the Akhunbabayev Canal, is connected to the irrigation network, so water consumption is slightly higher in spring and autumn, and slightly lower in winter and summer. (Table 2)

Table-2

Months	Water consumption over the years (m^3 / s)			Average water consumption per month (m^3 / s)	Electric power (kW)
	2019	2020	2021		
January	1.895	1.233	1.497	1.541	17.971
February	1.666	1.260	1.471	1.466	17.096
March	2.581	2.503	2.561	2.54	29.621
April	2.684	2.798		2.741	31.965
May	2.726	2.492		2.609	30.426
June	1.708	1.654		1.681	19.603
July	1.164	1.750		1.457	16.992
August	2.078	2.434		2.256	26.309
September	2.646	2.582		2.614	30.484
October	1.477	1.684		1.580	18.426
November	1.769	1.729		1.749	20.397
December	1.355	1.094		1.224	14.274
Average water consumption (m^3 / s)	**1.980**	**1.934**	**1.843**	**1.92**	**Average power consumption (kW)** **22,797**
Average water consumption for 3 years (m^3 / s)	**1.92**				

The efficiency of this gravitational vortex micro-hydro power plant, designed for the discharge pool of the Faizabad pumping station, is 70%, the effective flow height is 1.7 meters. The annual dynamics of electrical capacities calculated using expressions (1) and (2) are shown in **Figure 4.**

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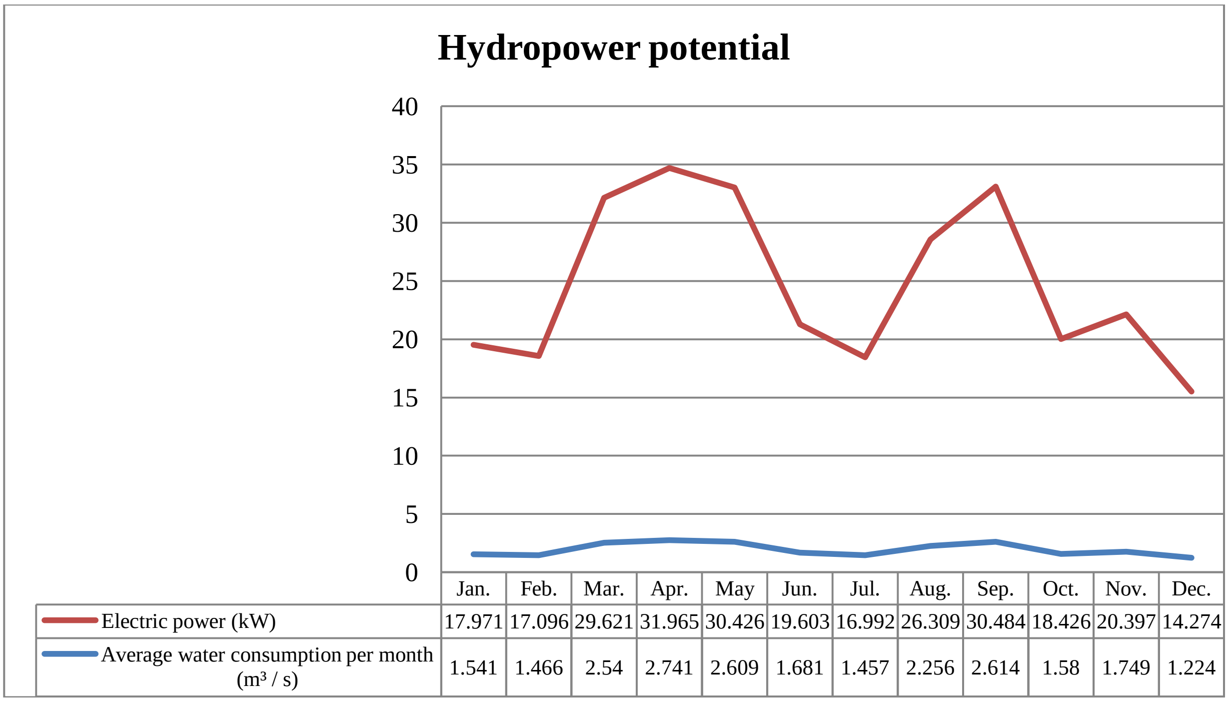

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Electric power (kW)	17.971	17.096	29.621	31.965	30.426	19.603	16.992	26.309	30.484	18.426	20.397	14.274
Average water consumption per month (m^3 / s)	1.541	1.466	2.54	2.741	2.609	1.681	1.457	2.256	2.614	1.58	1.749	1.224

Fig. 4. Hydropower potential of Faizabad pumping station discharge pool.

Table 3 shows the advantages and disadvantages, technical parameters, capital costs of this gravitational vortex micro hydroelectric power plant, which is designed for the discharge pool of the Faizabad pumping station. Quantitative units of project implementation costs are given in our previous article.

Table-3 VORTEX TURBINE SPECIFICATIONS

Description					
ADVANTAGES AND DISADVANTAGES		**TECHNICAL DATA**		**COST USD**	
Head	0.7 -3 m	**Effective head**	1.7 m	**Civil components**	6200
Efficiency	70-80 %	**water consumption**	1.192 m^3/s	**Turbine**	13200
Plant Constructions	Simple	**System efficiency**	70%	**Mechanical Transmission**	3000
Components of the civil building	Little	**Generated power**	22.8 kW	**Generator**	3000
Fish-friendly	Good	**Turbine specifications**	Ø1200mm, 100 rpm	**Control panel and electrical equipment**	3000
Mechanical Transmission	Gearbox/ pulley	**Generator type**	synchronous / asynchronous	**Installation cost**	6200
Durability	Good	**Mechanical Transmission**	pulley	**Total investment cost**	34600
water consumption availability	30 - 100%			**Generated power**	22.8 kW
Placement	In accordance			**Investment**	1518

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	with the existing water potential, very suitable to be applied along flat river flow and irrigation channels			**cost/kW**	
Others	Efficiency is still high in flow rate conditions under design conditions				

At the request of Uzbekhydroenergo JSC, 7 regions were selected based on a study conducted by the German company Tractabal Engineering GmbH in the Fergana Valley. Based on the hydropower potential of these areas, project values for the construction of micro-hydropower plants have been developed. According to him, the relative values of capital expenditures of 2000-3200 $ / kW are given according to the geographical location of the region [6]. In this project, as shown in Table 4, the investment cost is $ 1,518 / kW.

Gravitational vortex micro-hydroelectric power plants use circulating vortex energy inside a cylindrical basin. The water creates a strong vortex inside the basin and exits through a small outlet hole of the cylinder and joins the channel flow. The main advantage of gravitational turbines over large hydropower plants is that they have low environmental impact due to their low rotational speed and the absence of large dams, which are harmless to the underwater ecosystem, ie the fish world [1]. This gravity vortex turbine can be used in water treatment plants, irrigation networks related to irrigation works. Figure 5 shows a schematic of a gravitational vortex microhydroelectric power plant designed and implemented for the Faizabad pumping station discharge pool.

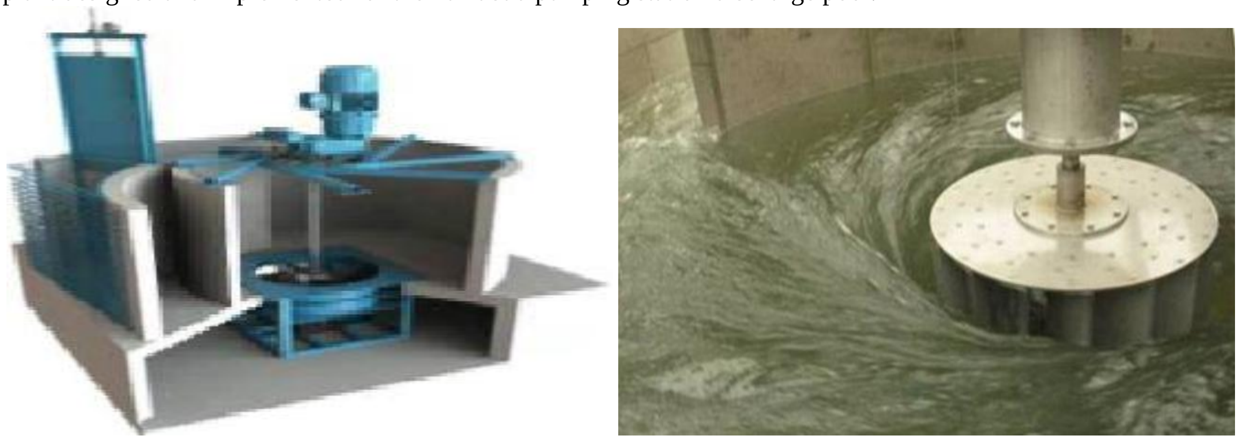

Fig.5. Gravitational vortex microhydroelectric power plant.

The infrastructure of a gravitational vortex microhydroelectric power plant is not very complex, that is, it can be built from local raw materials using a simple labor force. Due to the fact that the economy of the country is associated with the agricultural sector, the production and use of hydropower potential of existing irrigation networks and the establishment and development of its consumption as an autonomous consumer remains an urgent issue.

IV. CONCLUSION

According to the hydropower analysis, the parameters of the Fergana pumping station under the Syrdarya-Sokh Irrigation Basin Department and the Faizabad pumping station of the Energy Department are as follows: the minimum water consumption was 1,224 m^3 / s in February and the maximum was 2,741 m^3 / s in April. . Accordingly, the power was also found to be between 14,274 kW and 31,965 kW. Based on the above indicators, the average power generation capacity was set at 22,797 kW, and the capital cost of a gravitational vortex hydroelectric power plant of the same capacity was estimated at $ 34,605, and the project cost was estimated at $ 1,518 / kW. This relative value is much lower than the figure of $ 2000-3200 / kW set by Tractabal Engineering GmbH. It can be concluded that the

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systematic design of gravitational vortex microhydroelectric power plants for irrigation systems remains a promising issue.

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