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# RESEARCH ON THE EFFICIENCY OF USING HYDRO TURBINES IN PUMPING MODE AND FOR ELECTRICITY GENERATION


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**Abstract**: This article explores the prospects for developing a hydro turbine pump operation and electricity generation system using water flow energy. The system under investigation utilizes a hydro turbine that converts the kinetic energy of water into mechanical energy. This energy is transmitted simultaneously to the water pump and the electricity generator via a reducer. The study analyzes the efficiency of this dual-function system and identifies the optimal parameters for water resource management and energy production. The article evaluates various hydro turbine configurations, flow speeds, and system parameters, determining the most favorable conditions for maximum energy extraction and water lifting efficiency. Additionally, the practical application of such systems in areas with abundant water resources is discussed.



**Keywords:** flow energy, hydro turbine, pump, hydroelectric system, electrical energy, generator, kinetic energy of water, hydroelectric potential.


**Introduction.** In our country, the demand for energy is increasing rapidly year by year. The growth of this demand has become one of the key issues for the country's industry and economy. The main reasons for the increase in energy demand include population growth, the acceleration of urbanization processes, the development of new industrial sectors, and, most importantly, economic growth. This, in turn, highlights the need for substantial efforts in developing new types of energy sources, diversifying energy resources, stabilizing energy supply, and ensuring energy security.

There are vast opportunities for utilizing renewable energy sources in Uzbekistan, and significant work is being done to develop them. In particular, the potential for solar energy utilization is enormous in Uzbekistan, as most of the country's territory is sunny for most of the year, which increases the opportunities for large-scale use of this energy source. Several international projects for building solar power plants are being implemented by the government. For example, in 2022, the 100 MW Nur Navoiy Solar

Park (Navoiy) and the Nurabad Solar Park (Samarkand) solar power plants were commissioned[1].

At the same time, considerable attention is being paid to the field of hydroenergy. The large rivers, canals, and reservoirs in our country demonstrate the significant hydroelectric potential. Hydroelectric power plants (HPPs) can play an important role in ensuring the energy security of Uzbekistan as a clean and sustainable energy source. The construction of small and medium-sized HPPs can further strengthen the country's energy balance and provide energy production without harmful gas emissions.

Currently, 85% of the electricity produced in our republic is generated by thermal power plants using natural fuels. Only 14.5% of electricity is generated by HPPs. Renewable hydroelectric energy sources, which can be used repeatedly, occupy an important place in the energy system of our country.

Since Uzbekistan is a developing agricultural country and located in an arid zone, crop production is carried out through artificial irrigation. To deliver irrigation water, Uzbekistan's irrigation system includes 75 large and medium-sized main and medium-sized canals, 207 hydraulic structures, 172,200 km of internal irrigation networks, 56 reservoirs with a total volume of 19.6 billion m3, and 25 flood control reservoirs.

In the implementation of energy sector projects in Uzbekistan, international experience is being studied and the development of renewable energy sources is being encouraged. As a result of these efforts, significant progress is expected in stabilizing the country's energy balance, ensuring energy independence, and strengthening economic stability. The use of renewable energy sources, especially in solar and hydroenergy, will increase Uzbekistan's energy production capacity and provide opportunities for stabilizing energy supply. Based on this, the country's wide use of environmentally clean and sustainable energy sources will not only supply the domestic market but also create new opportunities for energy exports [1-10].

Types and quantities of renewable energy sources in the territory of the Republic of Uzbekistan (million tons of oil equivalent) [1].

**Table 1.**

| Types of Renewable Energy Sources | Gross Potential | | Technical Potential | | Utilized | |
|---|---|---|---|---|---|---|
| | mln.t. n.e | MVt×s | mln.t. n.e | MVt×s | mln.t. n.e | MVt×s |
| Solar Energy | 50973 | $592,9\times10^9$ | 176,8 | $2,08\times10^9$ | - | - |
| Wind Energy | 2,2 | $25,6\times10^6$ | 0,4 | $4,7\times10^6$ | - | - |
| Hydropower | 9,2 | $107\times10^6$ | 1,8 | $21\times10^6$ | 0,6 | $7\times10^6$ |
| Biomass Energy | 10,8 | $125,7\times10^6$ | 4,7 | $54,7\times10^6$ | - | - |
| Geothermal Water Energy | 0,4 | $4,7\times10^6$ | - | - | - | - |
| **Total** | 50984,6 | $593\times10^9$ | 179,0 | $2,1\times10^9$ | 0,6 | $7\times10^6$ |

From the table above, we can see that the main part of the renewable energy potential in our republic is provided by solar energy. Following that, biomass and hydropower energy potential take the next positions.

**Methods.** Using a hydro turbine operating on water flow energy for both pumping and electricity generation systems at the same time leads to significant energy savings and a reduction in harmful gas emissions affecting the environment. In such a system, the kinetic energy of the water is transmitted through the turbine to the pump. The rotary motion created in the pump is then converted into electrical energy by the generator (Figure 1).

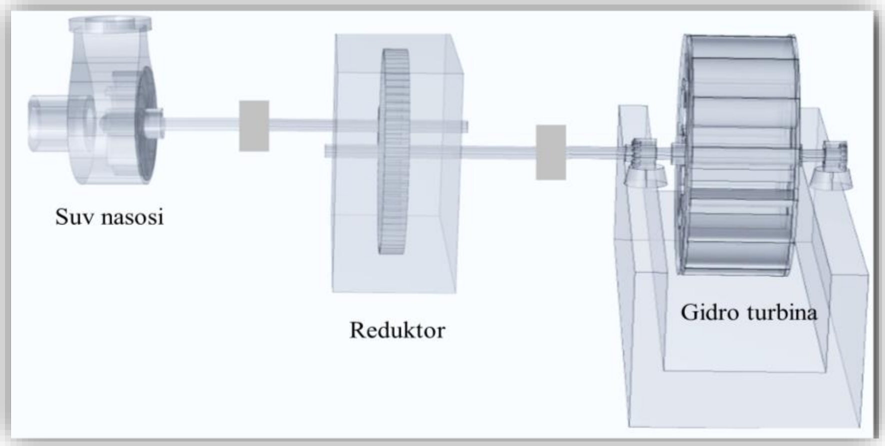


**Figure 1.** General view of the hydro turbine pump system

In recent years, considering that nearly 20% of the electricity produced in our republic is consumed by agricultural consumers, the use of such a system to meet the demands of irrigation and electricity will allow for high efficiency.

There is an opportunity to use such hydroenergy systems in various configurations of micro HPPs (Figure 2). Therefore, hydroelectric pumps can be used in areas with varying flow speeds and altitudes.

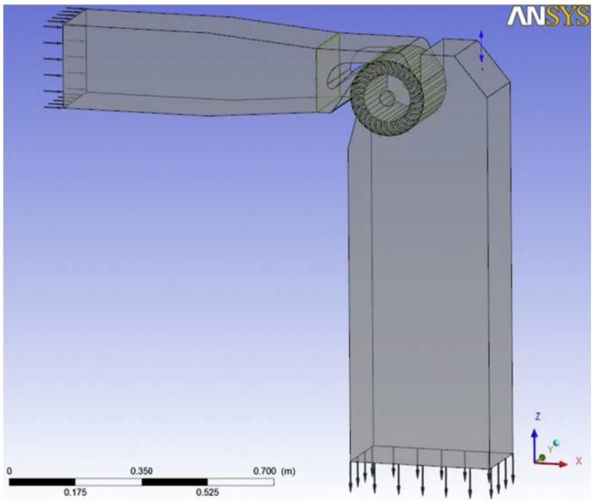


**Figure 2.** General view of the system created in the ANSYS software

When using a hydro turbine pump and electricity generation system based on the kinetic energy of water flow, the following calculations need to be performed.

**Figure 3.** General view of the hydroelectric pump prototype

**Determining the Flow Energy of Water:**

The flow energy of water refers to its kinetic energy, which is used by the hydro turbine. This energy is calculated using the following formula:

$$E_k = \frac{1}{2} \cdot \rho \cdot Q \cdot V^2$$

In this case, $E_k$ – kinetic energy of the water flow (W), ρ – water density (kg/m³), Q – water flow rate (m³/s), V – water flow velocity (m/s).

**Determining the Power of the Hydro Turbine:**

The power of the hydro turbine is determined using the kinetic energy of the water. This can be calculated using the following formula:

$$P_t = \eta_t \cdot E_k$$

Where: $P_t$ – hydro turbine power (W), $\eta_t$ – turbine efficiency (usually around 80% to 90%).

**Determining the Turbine Radius:**

To determine the radius of the turbine and other dimensions, the hydraulic diameter and velocity are calculated accordingly. The formula for the radius is:

$$r = \frac{V}{\omega}$$

Where: r – turbine radius (m), V – water flow velocity (m/s), ω – turbine angular velocity (rad/s).

**Calculating the Angle of the Turbine Blades:**

To determine the optimal angle of the turbine blades, the angle between the water flow and the blades needs to be calculated. The formula for the blade angle is:

$$\theta = tan^{-1}\left(\frac{V_r}{V_t}\right)$$

Where: θ – angle between the blades (degrees), Vr – relative velocity (m/s), Vt – tangential velocity (m/s).

**Calculating the Pump Power:**

The hydro turbine drives the pump to lift the water. The power required by the pump can be calculated using the following formula:

$$P_n = \frac{Q \cdot \rho \cdot g \cdot H}{\eta_n}$$

Where: Pn – pump power (W), Q – water flow through the pump ($m^3$/s), ϱ – water density (kg/$m^3$), g – gravitational acceleration (9.81 m/$s^2$), H – pump head (m), $\eta_n$ – pump efficiency.

**Calculating the Electrical Energy Generation:**

The hydro turbine generates electrical energy through the generator. The electrical power produced can be calculated using the following formula:

$$P_e = \eta_n \cdot P_t$$

Where: Pe – electrical power generated (W), $\eta_n$ – generator efficiency, $P_t$ – turbine power (W).

**Determining the Overall System Efficiency:**

The overall efficiency of the system is calculated by multiplying the efficiencies of all its components, such as the turbine, pump, and generator. The formula for the total system efficiency is:

$$\eta_{umumiy} = \eta_t \cdot \eta_n \cdot \eta_e$$

**Material Selection and Design:**

It is necessary to select materials for the turbine blades and other components. For example: steel, chromium-plated iron, stainless metals.

**Additional Calculations:**

The weight of the turbine blades and the weight of the material required for the central shaft are determined. These are calculated based on structural and thermal analysis.

**Calculating the Weight:**

The total weight of the hydro turbine is determined by calculating the mass of its components.

$$m_{umumiy} = m_{pichoqlar} + m_{o'q} + m_{qobiq}$$

Each mass can be calculated using volume and density. The sequence of these steps and formulas forms the necessary calculation sequence for fully developing the system[11,15].

**Results. Efficient Use of Water Flow Energy:** According to the results of the research, utilizing the kinetic energy of water flow is crucial in developing environmentally friendly energy sources and efficiently using natural resources. Through the use of hydroturbine systems, the kinetic energy of water is simultaneously converted into electrical energy via the pump and generator, thus increasing energy efficiency.

**Reduction in Operational Costs**: The simultaneous operation of the hydroturbine pump and generator significantly reduces operational costs. The use of such a system optimizes energy consumption and also reduces maintenance costs.

**Suitability for Small and Medium-Scale Hydroenergetic Systems**: Based on optimal design and efficiency analysis, this system proves to be beneficial for small and medium-scale hydroenergetic projects. These systems can effectively improve electricity supply and develop water supply systems in rural areas.

**Technical and Economic Efficiency**: During the research, the technical parameters and efficiency of the system were analyzed. The results show that the hydroturbine pump and electricity generation system is economically efficient in the long run, and its adaptability to operational conditions ensures its economic sustainability.

**Sustainable Development and Energy Security**: From an ecological and energy security standpoint, the importance of this system is significant. By utilizing such systems, there is an opportunity for efficient use of renewable energy sources in our country, enhancing energy production and ensuring energy security. This also creates new opportunities for energy exports[11-17].

**Discussions.** The research indicates that renewable energy sources, particularly solar, wind, and hydroelectric potential, offer significant promise for Uzbekistan's energy future. Among these, **solar energy** has the highest gross potential, as Uzbekistan enjoys a sunny climate for most of the year. This is an essential factor for large-scale solar energy projects. However, while solar energy offers tremendous potential, the **technical potential** for harnessing it is constrained by technology, storage capacity, and infrastructure. Despite this, solar energy remains one of the most viable renewable resources in the country.

**Hydropower** (or hydroelectric energy) stands as another vital renewable resource, with both significant **gross potential** and **technical potential**. While the country's rivers and reservoirs provide a notable resource for hydropower, only a small percentage of the potential has been exploited so far. This suggests that hydropower could play an increasingly important role in Uzbekistan's energy mix. The **exploited potential** of hydropower remains low, which opens doors for the development of micro and small hydropower plants, especially in rural and remote areas.

**Conculutions.** The prospects of a hydroelectric pump and electricity generation system using water flow energy have been analyzed. The use of the kinetic energy of water flow is especially important for efficient use of natural resources and the development of environmentally clean energy sources. Using a hydro turbine to simultaneously operate the water pump and electricity generator increases energy efficiency and reduces operational costs. This system, particularly suitable for small and medium-scale hydroelectric projects, can improve electricity supply in rural areas and contribute to the development of water delivery systems. Through the analysis of technical parameters and efficiency, optimal design and operational conditions are determined, and the economic aspects of the system are also highlighted. Overall, the approaches presented in the article contribute to ensuring sustainable development and energy security in the field of hydroenergy.

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