Substantiation of parameters of hydro turbines of micro-hydroelectric stations with an asynchronous generator

A I Ismailov, N A Samatov, Sh K Bakhramov*, B N Rayimdjanov, I F Sharipov

Institute of Agriculture and Agrotechnology, 1, Oliygoh ave., Andijan, 170613, Uzbekistan.

E-mail: shohrux.baxramov@mail.ru

Abstract. This article provides information that we have carried out calculations of the efficiency of using micro hydroelectric power plants. It describes how you can choose hydro turbines for micro hydroelectric power plants using an unconventional method with an asynchronous generator; how micro hydroelectric power plants can be useful to people who are isolated and live far from the mains; what elements are mandatory in the design of micro-hydroelectric stations; how pressure line allows increasing the energy of the working stream water, using more efficient types of jet-type hydro turbines; how electromechanical systems for converting the energy of water flows into electrical power of the required quality can be divided into new classes. Additionally, we mentions about the types of generators that are used for micro-hydroelectric stations and paid attention to the advantages and disadvantages of supply of energy and what details are playing an important role the choice of them.

1. Introduction

The ecological situation, the continuous growth of geographically separated and remote from electrical networks agricultural facilities of small capacity, located near water streams with heads from 1 to 6 m and a capacity of 1 to 100 kW, pose the problem of creating inexpensive and efficient autonomous automated micro-hydroelectric power plants with the purpose of meeting household and industrial needs for electrical energy.

The high energy density of water flows, ample opportunities for regulating their energy and the relative temporal stability of the flow regime of most rivers make it possible to use simple and cheap systems for generating and stabilizing the parameters of generated electricity. It is known that in Uzbekistan, electricity production is mainly carried out at thermal power plants, by burning fossil fuel. Few people know that to obtain 1 kW·h of electrical energy, 0.3 cubic meters of natural gas, or an average of 2.5 kg of coal is consumed [4], the explored underground reserves of which are not infinite. Renewable energy power plants (REPS) - hydraulic power plants (HPPs) - generate no more than 10% of the total electricity production in the country. In this regard, the Resolution of the President of the Republic of Uzbekistan dated July 10, 2020 PQ-4779 "On additional measures to increase the energy efficiency of the economy and reduce dependence on fuel and energy products by attracting available resources” puts emphasis on paying broad attention to this development [1].
2. Methods

Usually, a micro-hydroelectric power station contains in its design such mandatory elements as a hydraulic turbine, an electric machine generator, an output voltage stabilization system and a number of elements, the presence and design of which depend on the type and characteristics of the station: certain hydraulic structures, valves, ballast loads, etc.

As hydraulic motors that convert the energy of the flow into mechanical all types of hydraulic turbines are used to one degree or another: rotary-blade, radial-axial, pulse, axial, turbines with horizontal and inclined axes of rotation, etc.

As we evaluated, micro-hydroelectric power stations do not require the construction of complex hydraulic structures - dams. Therefore, their turbines are installed either in a free flow of water or in a special pressure pipeline. For work in a free flow of water, mainly active-type water turbines are used, a typical example of which is water mills. The advantage of active turbines is their maximum simplicity and relative rigidity of mechanical characteristics. However, the low speed and low efficiency of active hydraulic motors limit their use in hydropower.

The pressure line allows increasing the energy of the working stream water, using more efficient types of jet-type hydro turbines. The power developed by the hydraulic turbine is determined from the expression:

$$P_T = \frac{\gamma Q H \eta_T}{\Omega}$$

where $\gamma$ is the weight of a unit volume of water; $Q$ - water consumption; $H$ - working head; $\Omega$ - angular rotation frequency; $\eta_T$ - full efficiency turbines.

Obviously, the capacity of a hydraulic turbine with a pressure pipeline will not depend on the water regime of the river if its minimum flow exceeds the amount of water entering the pipeline. The diameter of the pipeline and the difference in height between its upper and lower points determine the design capacity of the station. The micro HPP pipeline can be made of steel, concrete, rubber and other pipes widely used in irrigation systems. Its cost depends significantly on the terrain, determining the feasibility of using micro-hydroelectric power plants, primarily in mountainous areas with large river bed slopes. Correct use of the terrain, as well as the simplest structures such as diversion channels, in many cases, can reduce the length and, accordingly, the cost of the pressure pipeline. It should be noted that the power and speed of the turbine determine the design power of the generator, its weight, dimensions and cost. In the general case, these parameters are related by the relationship [6]:

$$\frac{D^2 \cdot l_\delta \cdot \Omega}{P} = \frac{\sigma}{A \cdot B_\delta}$$

where $D$ is the inner diameter of the stator of an electric machine; $l_\delta$ is the estimated length of the air gap; $P$ - calculated apparent power; $\Omega$ - rotation frequency; $A$ - linear load; $B_\delta$ is the magnetic induction in the air gap; $\sigma$ is the coefficient of proportionality. With relatively constant values of the design power and electromagnetic loads of the generator, its volume, characterized by the product $D^2 \cdot l_\delta$, is determined by the rotation frequency $\Omega$. From this point of view, high-speed hydraulic turbines allow the use of generators with good weight and dimensions and low cost. In the case when the rotational speed of the micro-hydroelectric turbine is low (practically less than 400 rpm), it is advisable to use multipliers. This allows you to achieve maximum efficiency conversion and the minimum mass of the installation as a whole.

3. Results and discussions

As a result, we evaluated low-pressure micro-hydroelectric power plants, propeller-type jet hydro turbines with a nominal speed of 1000 to 3000 rpm which are predominantly used. This type of turbine makes it possible to exclude the multiplier from the hydropower plant.
Figure 1 shows the experimental characteristics of an unregulated propeller hydraulic turbine of the K-245 type, with a diameter of 289 mm, at a head of $H = 9$ m, for two positions of opening the guide vane. As can be seen from Fig. 1, the rotational speed of the hydroelectric unit can vary significantly depending on fluctuations in the magnitude of the load and the energy of the working water flow. Consequently, when creating a micro-hydroelectric power plant, it is necessary to pay special attention to the systems for stabilizing its operating modes [3].

The analysis showed that the electromechanical systems for converting the energy of water flows into electrical power of the required quality can be roughly divided into five main new classes:

1) systems with stabilization of the hydraulic turbine speed by impact on the elements of hydraulic equipment;
2) systems in which between the hydraulic motor and the generator set-constant speed drives are added, allowing to analyze the rotational speed of an electric machine;
3) systems that stabilize the frequency of the output voltage using special designs of electrical machines-generators of stable frequency at variable frequency rotation;
4) systems using static frequency converters, converting the voltage of a variable frequency generator rotation;
5) systems based on the principle of brake motor control replacement of the generator by introducing additional controlled load.

It should be noted that in addition to the indicated stabilization methods voltage micro-hydroelectric power station, their combinations can be used in various combinations. The first and second classes of power plants assume the use of various electro and hydro-mechanical regulators, others are built on the basis of valve electric machines. Specified section the development of stabilization systems corresponds to various principles of regulation he output voltage of the micro-hydroelectric power station.

Power control systems hydraulic turbine or using constant speed drives, control the drive motor of the generator by regulating mechanical energy of an electromechanical converter. Stations on the basis
of machine-valve systems regulate the electrical parameters installation. Accordingly, the properties of micro hydroelectric power plants, built using various principles of output stabilization parameters will differ significantly.

Generally, generators of changes are mainly used in micro hydroelectric power plants current of synchronous or asynchronous types. The advantages of asynchronous generators are high reliability, small size, low cost, ease of inclusion in parallel work. To the main their disadvantages include the need for a capacitor bank to self-excitation and the relative complexity of regulating the output voltage. Synchronous machines are somewhat large and massive and more expensive than asynchronous [2]. At the same time, in synchronous generators, the rotor and the exciter are the most complex and large units, the mass of which reaches 50% or more of the total mass of the generator, which creates a significant laboriousness in the manufacture and installation of synchronous machines. For example, the mass of a 100 kW generator reaches 1400 kg. Taking this into account, asynchronous generators have recently begun to be used at small hydroelectric power plants both in our country and abroad. Asynchronous machines of the same power have a mass 2-2.5 times less. For example, the mass of an asynchronous generator with a capacity of 10 kW reaches only 420 kg. When using an asynchronous machine with a power of 1.5 kW at a transportable hydroelectric power station, the weight of the power unit is only 50 kg. This allows two workers to install it manually (without lifting devices) in nomadic conditions[5].

The use of asynchronous machines greatly simplified the installation of small hydroelectric power plants in difficult off-road conditions in mountainous areas and began to facilitate their spread at agricultural facilities remote from the sources of centralized power supply. According to our studies, Uzbekistan’s climate can be suitable for both types of generators, but asynchronous generators are more preferable.

4. Conclusion

1. Creation of micro-hydroelectric power plant allows one to pay special attention to the systems for stabilizing its operating modes.
2. Despite some disadvantages, micro HPP with asynchronous generators are advantageous in terms of low cost, simplicity of design and operation in normal modes, resistance to external accidents, and a significant resource.
3. Micro hydroelectric power station is a promising environmentally friendly source of general-purpose electricity.
4. Fundamentally, the process of converting mechanical energy flow of water into an electric current can be carried out using a fairly wide range of devices, including those not intended specially designated for use in micro hydroelectric power plants. The problem is involved in optimizing this transformation in order to obtain the best consumer and operational properties of power plants.

References
[1] Ismailov A I, Baxramov Sh K 2020 Actual problems of modern science education and training 7 239-243
[2] Baxramov Sh K, Ismailov A I 2020 Global Science And Innovations 2020: Central Asia. 3(3) 182-184
[3] Lukutin B V, Obuxov S G, Shandarova E. B. 2001 Autonomous electric supply from microhydropowerplants (Tomsk)
[4] Alimhodzhaev Sh K, Zakhidov O U, Taniyev M H  2019 Journal of Tashkent Institute of Railway Engineers 15(4) 79-86
[5] Klychev Sh I, Muhammadiev M M, Avezov P P ,Potaeiko K D 2010 Unconventional and renewable sources of energy (Tashkent - Fan va texnologiya) p 192
[6] Ponomarenko A.S 2013 Cuban Agrarian university 89(05) 1-10