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System approach to renewable energy use in power supply

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System approach to renewable energy use in power supply

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Abstract. Based on the analysis of current developments in small hydropower plants, the structural scheme and installation scheme of a dam without hydropower were developed. According to the developed scheme, a small hydroelectric power plant was installed and prepared for testing. During the study, an analysis of 3 magnitudes (V), voltage frequency (Hz) and sinusoidal coefficient (%) that determine the quality indicators of electricity was presented. The obtained results are compared with the value limits given in the international standard normative document.

1. Introduction

Scientific research aimed at expanding the use of non-conventional and renewable energy sources, saving hydrocarbon fuel energy resources and stabilizing the ecological balance is gaining importance in energy practice worldwide. In this regard, the long-term national energy programs of developed countries set a task to increase the share of renewable energy sources to at least 20% [1]. In this regard, in the world practice, the use of micro-hydroelectric power plants, which are one of the largest sources of renewable energy in the power supply system, is in full swing, turn, special attention is paid to the development of this industry.

In the world, special attention is paid to the scientific supply of reliable and environmentally friendly technologies for electricity generation. Of particular importance in this area, including the modeling of structural and operating parameters of micro-hydropower plants operating at low pressure water flows, improving the design, development of technology that increases the efficiency of use in low pressure water flow systems.

There are foothills and small streams in the country, where it is possible to build micro-hydroelectric power plants to generate electricity. But so far little attention has been paid to the construction of such small-capacity hydropower plants. Until now, the main focus has been on the construction of large hydropower and thermal power plants, which have neglected to generate electricity from facilities with such small water flows. With this in mind, one of the key issues is to identify areas where small hydropower plants can be built for the efficient use of natural water flow energy and to select suitable hydraulic units for these areas.

Small-capacity hydropower plants are divided into the following types [2]:

a) micro-hydro power plant with a capacity of up to 0.1 MW;

b) mini hydropower plant with a capacity of 0.1 to 2 MW;

c) small hydropower plant, capacity up to 10 MW (these power values are given for one unit).

Small hydropower plants are also divided into types by pressure [3]:

a) low pressure H= up to 20 m;

b) medium pressure H= 20 - 100 m;

c) high pressure H> 100 m.

In the foothills, it is advisable to start the water supply to the hydraulic turbine from a small hydropower plant through special water pipelines (pipes, canals and tunnels). In mountainous areas, the presence of large slopes makes it advisable to use a low-cost derivation hydropower plant.

2. Methods

Based on the analysis of the current developments for small hydropower plants [6, 8, 9, 10], the following structural scheme and installation scheme (Figure 1) of the dam-free hydropower plant are presented.

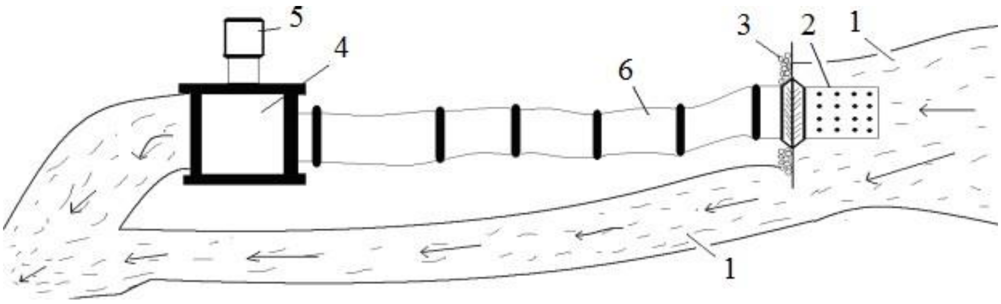

Figure 2. Installation scheme of a mobile hydroelectric power plant: 1 stream; 2- water intake hydraulic structure; 3-dam; 4-turbine; 5-hydrogenerator; 6 pressure width

Water collection devices shall ensure uninterrupted supply of water to the derivation at the specified water consumption and the installed operating period. In case of emergency of station equipment, their inspection and repair, in order to protect water flow paths from foreign objects (waste, ice, etc.) and when the pressure in the water supply system drops, it is allowed to stop the inflow of water into the derivation. The main function of the dam is to divert water to the derivation system. In addition, the dam must ensure that excess water escapes. For this reason, small watercourses are installed on water collection devices to discharge excess water up to one meter in height. This height is necessary to fill the water receiver with water.

If it is possible to collect water without building a dam, then it is possible not to install it at all. Cleaning the water in the catchment from sand and gravel is improved by using inclined dams that create transverse circulation. The dam is formed mainly using natural stone piles and stones. In order to reduce water leakage from such dams, their inner surface is covered with reclamation fabrics (Figure 2). Due to the small size of the dam basins that discharge excess water, they must be protected from sand, gravel, stone and natural waste that are abundant in mountain rivers. For this purpose, a discharge hole (8) is installed at the entrance to the water intake, through which the waste collected in front of the entrance is discharged to the lower bay. The water receivers are equipped with a debris trap (1) and a repair barrier (2). Due to the small volume of water collected, the barrier and the barrier are equipped with a lifting device using a slave.

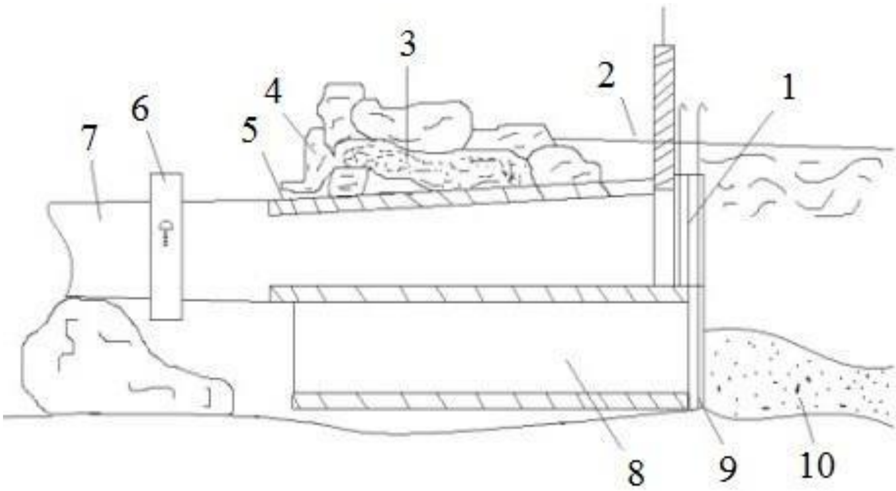

Figure 2. Water collection device of a small hydroelectric power plant: 1 is the barrier holding the waste; 2- repair zatvori; 3- reclamation fabric on the inside of the dam; 4-stone dam; 5-water receiver; 6-connecting rods: 7-pressure width; 8-water dispenser; 9-water bottom sender hole valve; 10-gravel piles in front of the catchment

The surface area of the water intake wind (V_p= 0,25 …..0,5 m/s) [4]:

$$Sp = \frac{Q}{Vp} \quad (1)$$

where: Q- water consumption of the hydropower plant is m^3/s.
The water intake window is installed in the upper bay below the lower water level. In this way, it is protected from objects that hit the barrier and float on the surface of the river.
The total pressure consumption in the water intake is the sum of the local consumption, which is found by the following formulas:

$$n_{con} = \frac{K_{ИТ} V^2}{2g} \quad (2)$$

Where: K_{it} is the sum (total) coefficient of pressure in the water intake, usually K_{it} = 0.15-0.3;
The average flow velocity in a *V*-pressure water basin is m/s; g = 9.81m/s^2 free fall acceleration.
The pressure pipe is assembled from several sleeves of the same diameter and a conical sleeve. They are attached to each other using couplings and clamps. The device is filled by means of a flexible top mounted on the water flow required for operation. Due to the length of the shaft and more than 40 installed shafts, the pressure that drives the turbine is created.
The use of flexible pipes as a small hydroelectric pipeline allows it to be installed without adjustment in complex mountainous terrain. In addition, the need for dams and other stationary devices has been eliminated, making the small hydroelectric plant portable. The pressure flow (m) and the flexible pipe λ are found in the pressure section of the water flow.

$$\Delta h = \frac{0{,}083\ \lambda\ LQ^2}{d^5} \quad (3)$$

where: λ is the coefficient of friction of the water on the pipe surface (usually 0.02… 0.03 m^2/s); *Q*-current consumption, m^3/s; *d* - diameter of the pipeline, m; *L* is the length of the pipeline, m.

3. Results and Discussion

The following sequence should be followed during the installation and testing of a small hydropower plant:
1. The water supply trays are connected to each other by means of a coupling with a clamp and laid from the highest point;

2. Construction of a hydraulic structure to control the flow of water into the area and the closure of the drainage trays to this water supply basin (Figure 3b);
3. When closing the trays to the water supply basin, install a grate between them to trap various wastes coming in the water stream;
4. Concrete pavements for the installation of water turbines of small hydropower plants are made in accordance with the norms and rules of reinforced concrete construction of the Republic;
5. The water supply lattice is connected to the wheel (Figure 3a);
6. The generator, reducer and power unit are installed in a place protected from precipitation (Figure 4a);
7. The wheel shaft is connected directly to the gear shaft;
8. The reducer is connected to the generator using a rubber band (Figure 4a);
9. The generator is connected to the power unit using a cable (Figure 4b);
10. The power unit is fixed to the ground with a pin;
11. The melter is prepared and it is connected to the melter of the power unit.

A low-pressure small anchor was selected to test the developed test specimen of a small hydropower plant (Figure 3a) and a hydraulic structure was constructed to control the flow of water entering the area (Figure 3b).

a) b)

Figure 3. Installation of the device (a) and hydraulic structure (b)

a) b)

Figure 4. Place of installation of the generator and reducer of the device (a) and the process of preparation of the generator and power unit for operation (b)

Thus, as described above, a test sample of a small hydropower plant operating on low-pressure watercourses created at a selected geographical location was installed. Every detail has been inspected for testing under natural conditions.

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The quality of electricity generated by a micro-hydroelectric power plant operating at low pressure water flows was checked using a measuring instrument that analyzes the quality of electricity [5]. The study focused on three dimensions that mainly determine the quality of electricity:
1. Voltage (V);
2. Voltage frequency (Hz);
3. Sinusoidal exponent (%).
The obtained results were compared with the value limits specified in the normative document according to the international standard [7].
In our study, our time interval was taken from 14:08 to 14:25. At the same time, all inspections were carried out at the same time. The obtained results (Figures 5, 6, 7) were analyzed using the Power vision program.

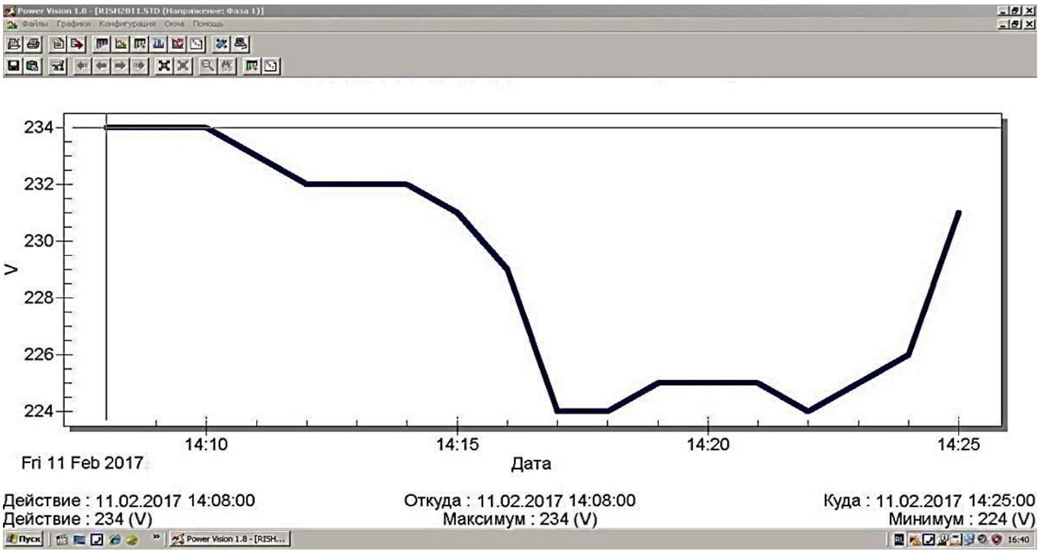

Figure 5. Alternating voltage, V

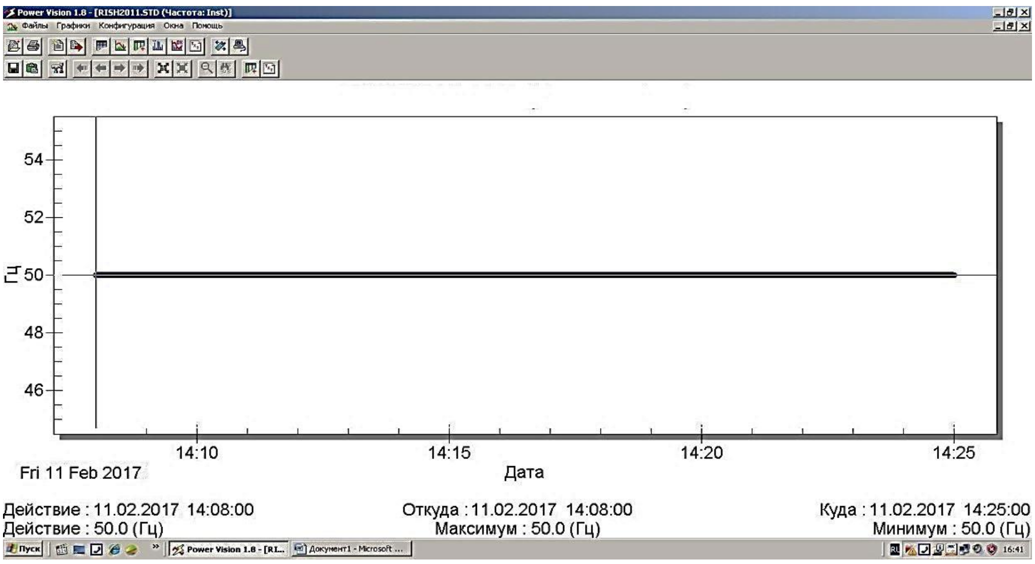

Figure 6. Voltage frequency

Figure 5 shows the alternating voltage waves obtained as a result of the study. In this case, we can see that the maximum voltage is 234 Volts, the minimum voltage is 224 Volts, and the average voltage is 229

Volts. This figure is ± 10% (198-242 Volts) of the AC voltage limit according to the international standard normative document. Hence, the 234 Volt voltage detected by us fully complies with the requirements set out in this document.

Figure 6 shows the voltage frequency obtained as a result of the studies. As can be seen from the diagram, the frequency value was 50 Hertz during the study and did not change. This figure is equal to 50 Hertz of the alternating voltage frequency according to the international standard normative document. Hence, the frequency of 50 Hertz detected in us fully complies with the requirements set out in this document.

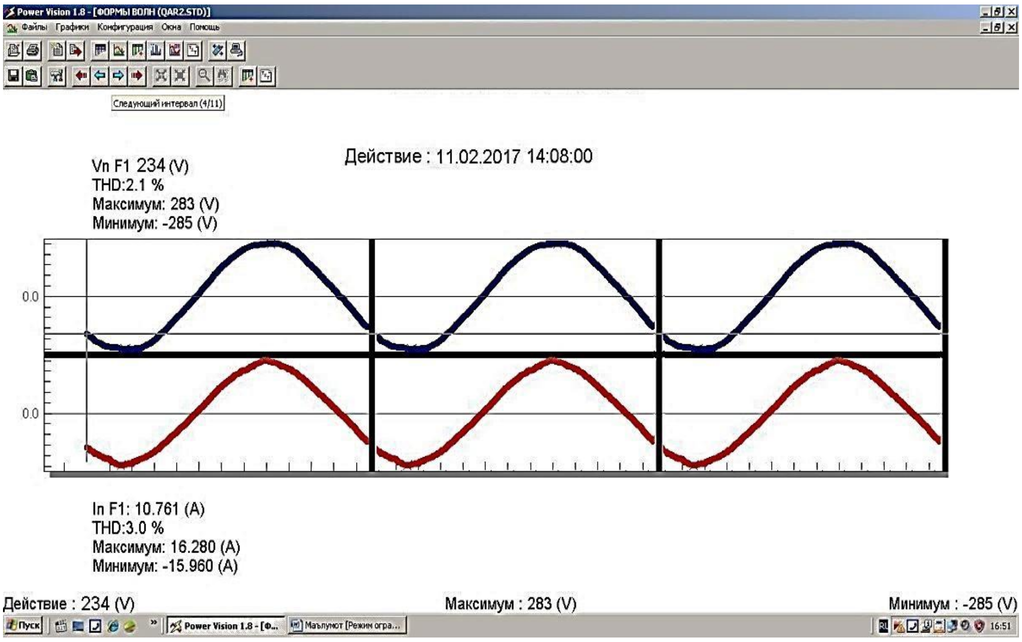

Figure 7. Sinusoidal exponent coefficients

Figure 7 shows the sinusoidal exponent coefficients obtained from the studies. As can be seen from the diagram, during the study, the sinusoidal index of voltage was 2.1% and the sinusoidal index of current was 3.0%. According to the international standard, the sinusoidal coefficients for voltage and current are set at 8%. Hence, the results determined by us fully comply with the established requirements of this document.

Thus, according to the results of the study, all quality indicators of electricity generated by a micro-hydroelectric power plant designed for low-pressure water flows: alternating voltage, voltage frequency and sinusoidal indicator fully meet the requirements of the international standard.

During the practical testing of the small hydropower plant, it became clear that if the location, water flow and hydrogenerator are chosen correctly based on the geographical capabilities of the region and (most importantly) the experience of making water turbines with different geometric dimensions is fully mastered, small businesses and farms can use this newly developed Small Hydroelectric Power Plant for their electricity consumption.

4. Conclusions

According to the results of the study, the quality indicators of electricity generated in a test sample of a micro-hydroelectric power plant designed for low-pressure water flows were checked. It was found that the alternating voltage, voltage frequency and sinusoidal coefficients fully comply with the requirements of the normative document according to the international standard.

The quality indicators (voltage (V) and frequency (Hz)) of the electricity generated were tested using a test sample. The results were compared with the value limits set out in the International Standard Normative Document. The identified sizes were found to fully comply with the specified requirements of the document. As a result, it is possible to provide consumers with quality electricity.

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The design dimensions of the developed device are compact and easy to use. As a result, it is possible to reduce the costs associated with its production.

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