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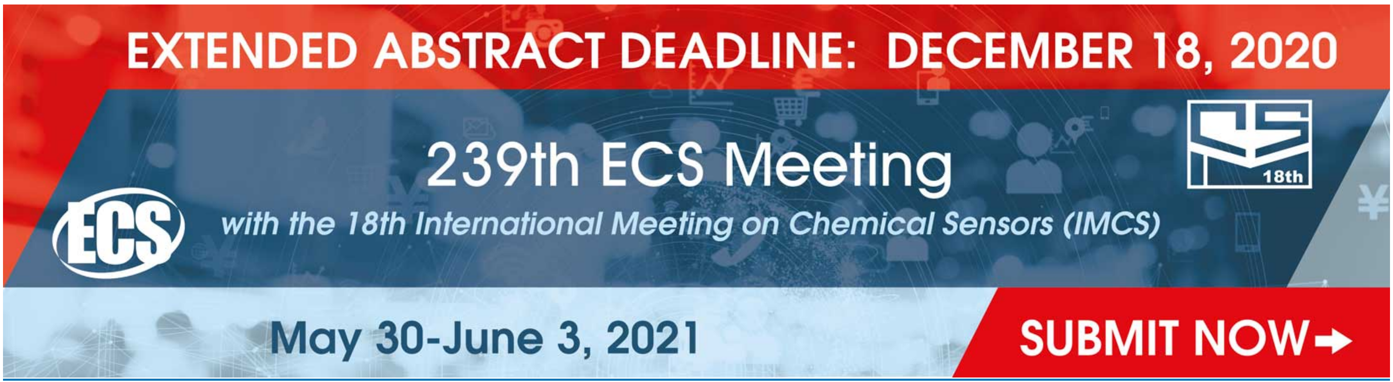

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Assessment of wind and hydropower potential of Bukhara region

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Abstract. This article presents a methodology for assessing the gross, technical and economic potential in the territory of the Bukhara region. Locations with high wind and hydropower potential were identified in the region, and the introduction of wind and micro-hydroelectric power plants was analyzed. According to the results of the study, the importance of wind and hydropower in the development of the socio-economic sphere of remote areas of the Bukhara region was studied.

1. Introduction

Currently, scientific research on stabilizing the ecological balance on a global scale and saving various hydrocarbon fuels that make up energy resources, expanding the use of unconventional and renewable energy sources are becoming increasingly important [1-20]. With regard to the development of the power supply system for consumers without harming the environment, special attention is paid to the use of one of the renewable energy sources in world practice and to scientific research in this area. There is a rapid development in the use of renewable energy sources such as solar, wind, biomass, geothermal and water energy. Due to the low cost of electricity generated from renewable energy sources, there is practically no environmental impact, such projects are becoming more and more affordable, and significant investments are made in them for the future development of research. The energy crisis associated with the reduction of fossil fuel reserves and the rapidly growing environmental problems determine the growing interest around the world in the use of natural renewable energy resources. Among them, the energy of water and wind flows occupies a very significant place in terms of reserves and scale of use. Hydropower is the most widely used renewable energy source worldwide, as it accounts for 19% of the world's electricity generated by both large and small power plants. The gross theoretical hydropower potential of the world's rivers is estimated at 52.0 billion PWh/year [21]. With regard to wind energy, during the period of 2019, the global wind energy market increased by 19%, adding about 60 GW of new capacities to the global electrical networks (of which more than 54 GW are on land and more than 6 GW are offshore) [22].

An increase in demand for electricity as a result of an increase in the population, as well as the creation of new industrial enterprises is observed all over the world, of course, our country also did not stand aside.

The availability of wind and hydropower resources in the country, the use of wind and hydropower from renewable energy sources is becoming increasingly important for various sectors of the economy, especially in the development of small business and private entrepreneurship. A special focus is on research and development aimed at developing reliable, environmentally friendly technologies to meet these needs. By accurately assessing the wind and hydropower potential of the Bukhara region, we can restore energy security and environmental problems in the region.

2. Method

2.1. Methodology for assessing the potential of wind energy

In the statistical processing of wind speed data, several distribution laws were used. The most common theoretical distributions are normal, exponential, Weibull, log-normal, Rayleigh and Gamma distributions. To date, the two-parameter Weibull distribution is widely used in the statistical analysis of wind energy potential in the regions [23].

The density and the Weibull distribution function are used to characterize the wind speed. Detailed information on densities and cumulative distribution functions is given in the following literatures [24, 25].

$$f(V) = \frac{k}{c} \cdot \left(\frac{V}{c}\right)^{k-1} \cdot e^{-\left(\frac{V}{c}\right)^k} \quad (1)$$

$$F(V) = \int_0^\infty f(V)dV = 1 - e^{-\left(\frac{V}{c}\right)^k} \quad (2)$$

Where: f (V) - probability density function; F (V) - cumulative distribution function.

To analyze the wind speed data, it is necessary to determine the two-parameter Weibull distribution, namely the parameters of scale and shape. Detailed information about the scaling factor and the aspect ratio is given in [26]:

$$k = \left(\frac{\sigma}{\bar{V}}\right)^{-1,086} \quad (3)$$

$$c = \frac{\bar{V}}{\Gamma\left(1+\frac{1}{k}\right)} \quad (4)$$

Where: $c -$ is the scale parameter, $k -$ is the shape parameter, $\Gamma -$ is the Gamma function.

According to the Weibull distribution function, it is possible to estimate the average wind speed, as well as the standard deviation of the wind, which are determined using the expressions [27]:

$$\bar{V} = c\Gamma\left(1 + \frac{1}{k}\right) \quad (5)$$

$$\sigma = c\left[\Gamma\left(1 + \frac{2}{k}\right) - \Gamma^2\left(1 + \frac{1}{k}\right)\right]^{1/2} \quad (6)$$

The formula for calculating the density power and energy of the wind flow for a given region using the calculated parameters of the Weibull distribution function [28]:

$$P_w = \frac{1}{2}\rho c^3 \Gamma(1 + \frac{3}{k}) \quad (7)$$

$$E_w = \frac{1}{2}\rho c^3 \Gamma(1 + \frac{3}{k}) \cdot T \quad (8)$$

2.2. Method for determining wind power potential at different altitudes by extrapolation

At certain altitudes, air density and wind speed vary. The density of the air flow, depending on the height, is determined as follows [29]:

$$\rho = \rho_0 - (1{,}194 \cdot 10^{-4} \cdot H) \quad (9)$$

Where: $\rho_0 -$ air flow density under normal conditions, ρ_0=1,23 kg/m^3; $H -$wind speed measurement height.

The wind speed value depends on the altitude. With increasing altitude, the wind speed increases. The following formula is based on the height of the wind speed:

$$V_2 = V_1 \cdot \left(\frac{H_2}{H_1}\right)^{\alpha} \tag{10}$$

Where: $V_2 -$ wind speed measured at a specific height; $V_1 -$ initial wind speed; $H_1 -$ station height; $H_2 -$ selected height; $\propto -$ coefficient of increasing wind speeds at different heights.

The coefficient of increasing wind speeds at different heights is determined by the following formula:

$$\propto = [0{,}096\, log_{10}(Z_0) + 0{,}016\, (log_{10}(Z_0))^2 + 0{,}24] \tag{11}$$

$Z_0 -$ roughness of the underlying surface. In the steppe regions Z_0 =0.1 м [30].

The scale and shape values at the specified height also change. These parameters are determined by the following expression [31, 32]:

$$k_{H2} = \frac{k_{H1}}{1-0{,}0881\ln\left(\frac{H_2}{H_1}\right)} \tag{12}$$

$$c_{H2} = c_{H1}\left(\frac{H_2}{H_1}\right)^{n} \tag{13}$$

$$n = [0{,}37 - 0{,}0881\ln(c_{H1})] \tag{14}$$

Using the parameters of the Weibull distribution calculated at different heights, we determine the density power and wind energy at certain heights using expressions (7), (8).

2.3. Methodology for estimating hydropower potential

To assess potential hydropower resources (excluding losses during the conversion of water energy into electricity), the gross hydropower potential is determined.

Gross potential is the theoretical amount of energy supplied or generated in a given area.

The action of the water force is determined by the difference in water levels at the beginning 1-1 and at the end 2-2 of the section under consideration (Figure 1). If the fall of a river section with a length L, m, is H, m, then at a water flow rate Q, m/s^3, equal to its average value at the beginning and end of the section, the work of the flowing water for one second, i.e. e. the power of the watercourse P, W or J/s, in the area under consideration is:

$$P = \rho g Q H = 9810QH, \tag{15}$$

where ρ - density of water, kg/m^3; g - acceleration of gravity, m/s^2. [33]

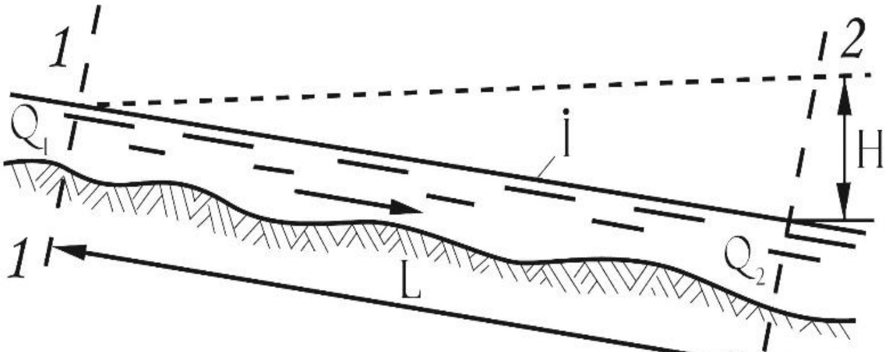

Figure 1. Schematic longitudinal profile of an irrigation canal section: *L – section length; H – fall of the plot; i- water surface slope; Q_1 u Q_2 water discharge in sections 1-1 and 2-2*

Since power in the power industry is usually measured in kilowatts, then

$$P = 9{,}81 \cdot QH. \tag{16}$$

Stream energy W, kWh, is determined by the product of power P by time t, s, is:

$$W = \frac{9{,}81 \cdot QHt}{3600} = \frac{VH}{367} \tag{17}$$

where $V = Qt$ - volume of used drain, m^3 [34].

Technical potential is part of the gross potential that can be realized using existing technologies.

In addition to potential hydropower resources, it is necessary to know that part of hydropower resources that can be used to generate electricity by creating a hydroelectric power plant - the so-called technical potential.

When determining the technical hydropower potential, all losses associated with the production of electricity are taken into account. These include the impossibility of full use of the runoff, losses for evaporation from the surface of reservoirs and for filtration from reservoirs, losses of pressure and power in the flow path and power equipment of HPPs [35].

$$P = 9.81QH\eta_t\eta_g \tag{18}$$

where Q - water discharge, m^3/s, used hydroelectric power station to generate electricity, H – head supplied to the turbine, determined by the difference in the levels of the upstream and downstream, η_t- efficiency of turbine, η_g- efficiency of the generator.

The efficiency of hydraulic turbines depends on their power, design, impeller diameter, and pressure changes. For turbines with impeller diameters from 1 to 10 m, the highest efficiency is reaches values from 0.89 to 0.95. For generators, depending on their power, the efficiency ranges from 0.92 to 0.98.

If we replace in (18) the coefficients $9.81\eta_{\mathrm{т}}$, η_g with one coefficient k, then, taking into account the possible deviation of the load of hydroelectric units of HPPs from the optimal, the average values of the coefficient k for HPPs with large and medium-sized hydraulic units will be 8.2-8.8 for small hydraulic units (capacity up to 5 MW) k is 7.8-8.0.

3. Results and discussion

Figure 2 shows the linear wind speed. Accordingly, the average wind speed is 3.404 m/s at 10 m, 4.4 m/s at 50 m and 4.9 m/s at 100 m.

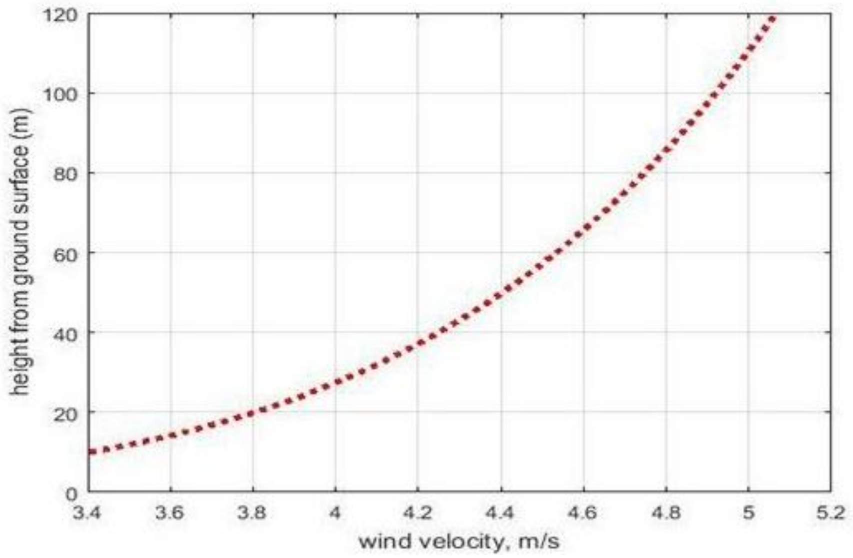

Figure 2. Average wind speed at different heights using the extrapolation method

Figures 3 and 4 show the values of wind power density and wind energy density at different wind heights. Accordingly, the density wind power and density wind energy at an altitude of 100 m were 164.79 W/m^2, 1443.59 kWh/m^2.

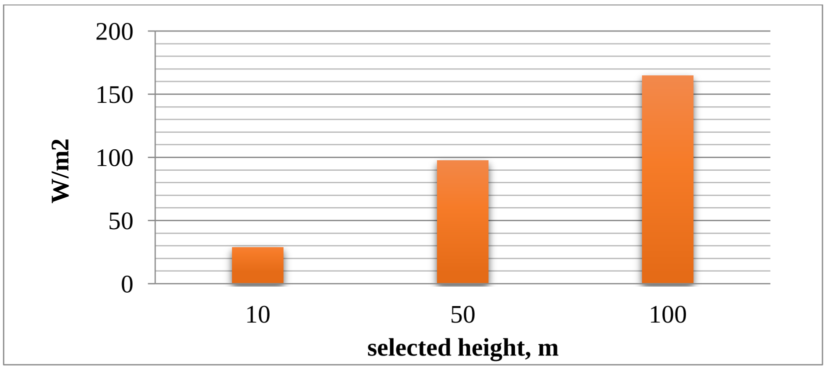

Figure 3. Average annual value for the Weibull distribution of density wind power at selected heights.

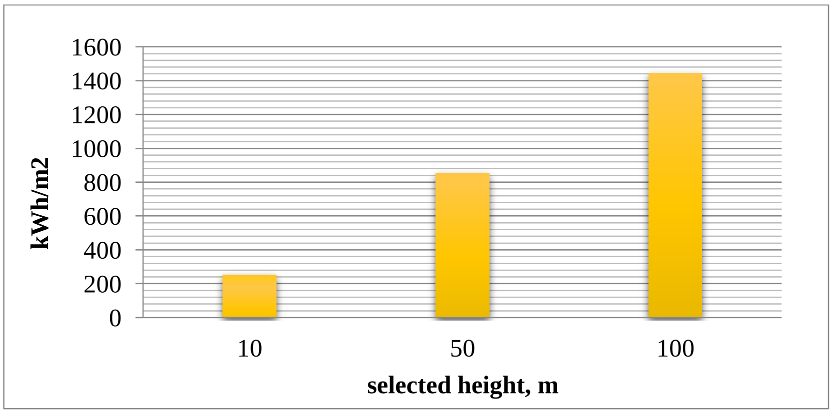

Figure 4. The average annual value for the density wind energy measured by the Weibull distribution at the selected heights.

With an increase in water consumption in the summer season, the gross potential of water energy also increases, which can be seen from our diagram. It can be seen that the smallest value of 13.9 MW falls on the month of March, with subsequent months the capacity grows and in July it takes its maximum value, which is 37.1 MW, which is almost 2-2.5 times more than in the spring period. In autumn, the gross potential declines and is released to the level of 16.1 MW in winter (Figure 5).

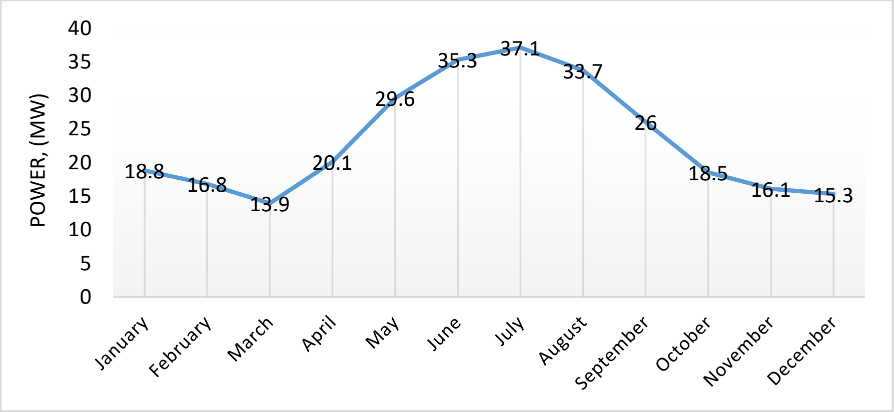

Figure 5. Gross hydropower potential for the period of 2018 for the territory of Bukhara region

Based on the data for 2018, it can be concluded that during the summer time there is more electricity generated in relation to the winter period. The data obtained was entered into a diagram (Figure 6).

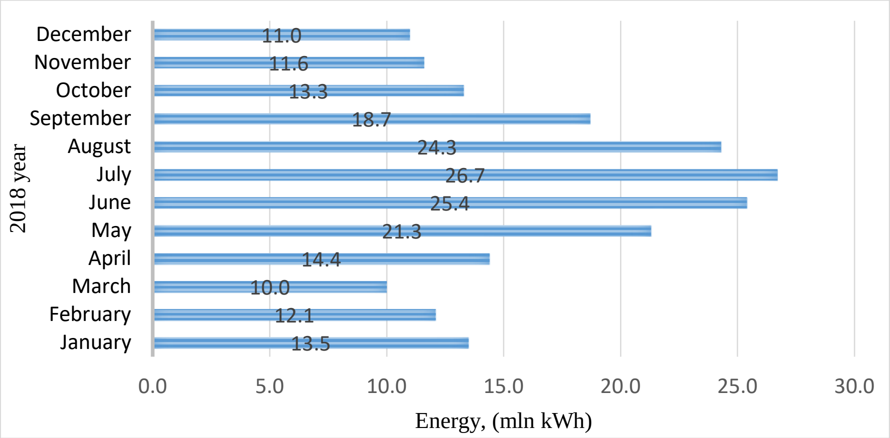

Figure 6. Watercourse energy (million kWh) of gross hydropower potential for the period of 2018 for the territory of Bukhara region

When determining the technical hydropower potential, considering losses, the efficiency was taken to be 0.82. The diagram shows that during the summer period the installed capacity reaches about 30 MW (Figure 7).

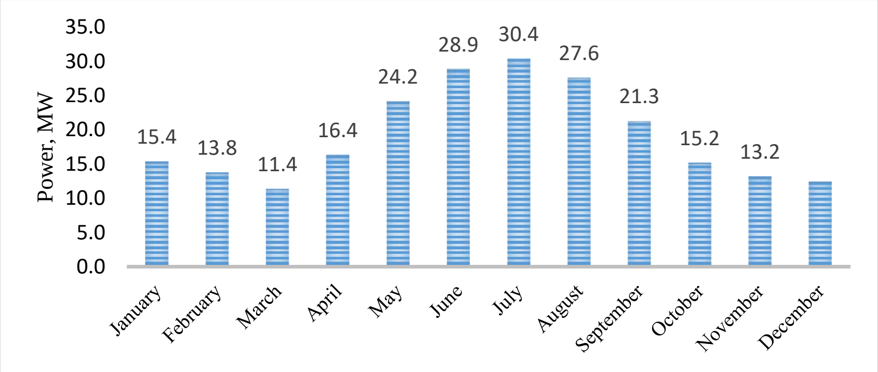

Figure 7. Technical hydropower potential for 2018 for the territory of Bukhara region

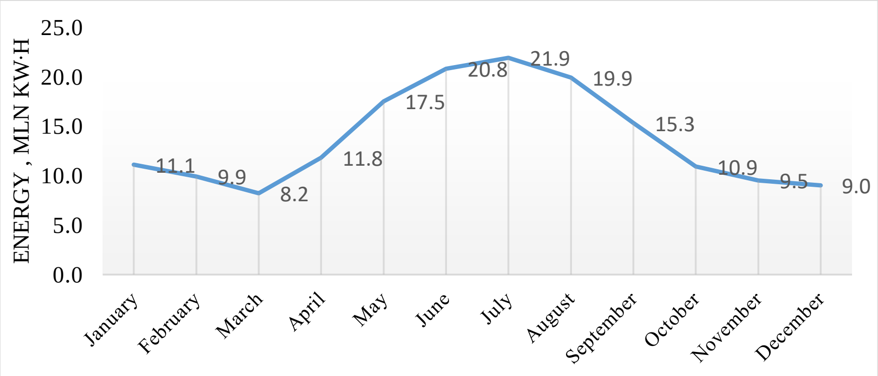

Figure 8. Energy of the watercourse of the technical hydropower potential for 2018 for the territory of the Bukhara region

After calculating the energy of the technical potential, we calculated the total electricity generation in the amount of 165.8 million kWh per year (Figure 8).

Economic hydropower potential means that part of the technical potential that is currently economically feasible to use [36].

4. Conclusion

The values of density power and wind energy at a height of 10 m were determined and analyzed using the Weibull probability distribution function. Accordingly, the average density wind energy is 40.98 W/m^2, and the annual density wind energy is 359.56 kW/m^2. The wind potential at different heights was determined using the Weibull distribution. Accordingly, the values of the density wind power and density wind energy at a height of 100 m were determined by extrapolation 164.79 W/m^2, 1443.59 kWh/m^2.

The study showed that the Amu-Bukhara canal has good hydropower potential, thanks to which the average capacity of the technical hydropower potential for the year is 19.2 MW, and its energy is 165.8 million kWh per year. Hydropower potential can serve as a way to solve problems with the electrification of remote areas with uninterrupted and reliable electricity, reduce greenhouse gas emissions to the atmosphere, and can also contribute to the development of small business, entrepreneurship, agriculture along the irrigation canal in remote areas of the Bukhara region. Considering the parameters of the Amu-Bukhara canal, further research will be aimed at creating an optimal design of a micro-hydroelectric power station with a special turbine and a low-speed generator, which will be adapted to the flows of the irrigation system of the area.

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