Factors Influencing the Determination of the Gyrosures Potential of Small Rivers

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Abstract. The article examines the main trends in the use of renewable energy sources in the world. The article examines the main trends in the use of renewable energy sources in the world. The use of renewable sources is associated with the depletion of reserves of carbonaceous minerals and a decrease in greenhouse gas emissions into the atmosphere. The article presents the main, according to the authors, reasons for the incorrect determination of the potential of small hydro resources in the Republic of Tajikistan. In recent years, many small hydroelectric power plants have been built, which are ineffective. For this, the authors propose a more detailed study of the watercourse regime and the determination of its potential for the minimum and maximum tributaries and the possibility of its use, the influence of hydrological, socio-economic factors on the determination of the potential of small rivers during the construction of small hydroelectric power plants. Zoning of small watercourses is proposed for a more detailed determination of the watercourse capacity and the possibility of constructing small hydroelectric power stations on them. The influence of altitude above sea level on the output of the rated power of installations of renewable energy sources is considered. As it shows, the experience of operation and the above statistical analysis at the existing small hydroelectric power plants with an altitude of SHPPs above sea level, their nominal capacity will decrease. The decrease in the nominal output power of small hydroelectric power plants with an air-cooling system is associated with the rarefaction of atmospheric air.

1 Introduction

Tajikistan, like most countries, does not have its own minerals, and all energy is generated using renewable energy sources, especially hydropower. The use of renewable energy sources has most of the unsolved problems associated with determining the potential and modes of operation of renewable energy sources depending on their geographical location. Today, there are still many unresolved problems in using renewable energy sources and a unified approach to solving all the shortcomings. The design of renewable energy installations requires both technical and economic, and social solutions. Since Tajikistan, in most of its cases, uses hydro resources, it is necessary to develop a unified approach to solving the problems of using small hydropower resources.

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1.1 Design assumptions for small hydro power plants

In this article, we will try to formulate objective obstacles that reduce the role and importance of small hydropower in the creation of decentralized power supply zones in certain hard-to-reach high-mountainous regions of Tajikistan based on the construction of small hydropower plants, in order to develop an event in subsequent chapters and propose ways and means to stimulate the use of renewable energy sources.

The main disadvantages of the design process in the field of small hydropower, which have been consistently repeated over the past 30 years of Tajikistan's independence, include the following:

- Lack of a scheme for the integrated use of water resources of the main rivers
- Lack of basin schemes for the integrated use of water resources;
- Lack of local schemes for the integrated use of water resources of individual watercourses;
- Lack of information on the resource base of small hydropower in the Republic;
- Poor hydrological knowledge of small streams;
- Lack of relevant law and clearly formulated state goals and priorities for the development of renewable resources, there are no governing bodies at regional levels and research centers;
- Low level of standardization and certification of equipment at the stage of their placement at manufacturing plants in other countries, underdeveloped infrastructure, lack of qualified service personnel, an insufficient amount of scientific, technical and technological developments, insufficient level of technical knowledge of decision-making organizations;
- Low public awareness of the possibilities of renewable resources, lack of widespread propaganda in the media of the possibilities and merits of these resources;
- Lack of necessary scientific and production personnel;
- Weak base of pre-design work;
- Low level of development of feasibility studies for the construction of small hydropower plants;
- Ignoring the many variations of technical solutions when choosing the main parameters of the project;
- Ignoring local conditions when choosing the main structures of the hydropower complex;
- Lack of a methodology for water and energy calculations to determine the guaranteed capacity of small HPPs;
- Ignoring climatic conditions when determining the winter mode of operation of small hydropower plants.

As you can see, a significant part of the listed problems is fundamental sections of designing hydropower facilities, including for small hydropower plants, many of which find their solutions only at the levels of state capabilities [1-3].

2 Methods

2.1 Design methods for small hydropower plants

Considering the above conditions for the development of small hydropower in the mountainous regions of Tajikistan, we consider it timely to develop practical methods for calculating the main energy indications of mini and small HPPs at the stage of feasibility study and construction. To do this, it is necessary to analyze the features of the hydrological
regimes of small watercourses and the associated processes of freeze-up, drift and slush in these high-mountainous regions of the Republic of Tajikistan.

Geographical location also influences the determination of the potential of the river. In this case, it is necessary to have at least 10-year data on the nature of flow changes in each section of the watercourse. In the mountainous regions of Tajikistan, the rivers mainly flow in shaped gorges and often on 10 km of the river's upper floodplain. There are no elementary conditions for the construction of SHPPs. Also, such sections are usually provided with low guaranteed capacities.

On the other hand, the use of the river along its entire length is more difficult in terms of the location of settlements and avalanche danger. As practice shows, depending on the height of the location of small hydroelectric power plants (SHPP) above sea level, several problems arise that must be taken into account when designing. Since most SHPPs are built according to the watercourse regime, it is necessary to determine the operation mode of SHPPs based on their watercourse regime. Basically, the choice of SHPP capacity is based on the efficient use of water resources of the existing river. To do this, it is necessary to show the average monthly water discharge in the river in an increasing form, keeping the monthly flow in the river, Figure 1.

![Graph showing average monthly water discharge in the river](image)

Fig. 1. Average monthly water discharge in the river

\[ q_1 = A_0 + A_1 t + A_2 t^2 + A_3 t^3 \text{, } m^3 / s \] (1)

By determining the water consumption, you can determine the capacity of the SHPP

\[ P_{CT} = \eta g H_p q_p, kVt \] (2)

where \( \eta \) is aggregate efficiency, \( H_p \) is estimated consumption, \( q_p \) — is estimated water consumption, \( m^3 / s \)
The intersection of the straight-line function to divide the annual work schedule of the SHPP into two stages:
1. 0–t1 – SHPP operates on a watercourse
2. t1–T – SHPP operates at rated power.

Based on the above, determine the annual flow through the SHPP by the expression:

$$Q_{rs} = 8.64 \times 10^4 \left[ \int_{0}^{t_1} q_t \, dt + q_p \left( T - t_1 \right) \right]$$  \hspace{1cm} (3)

Annual river flow

$$Q_{rp} = 8.64 \times 10^4 \int_{0}^{T} q_t \, dt, \ m^3$$  \hspace{1cm} (4)

When determining the potential of rivers, as noted above, it is necessary to divide them according to their location. The location of rivers in the regions makes it possible to more accurately determine their potential since the terrain in the regions differs significantly from each other.

To determine the hydropower potential of a watercourse using a modern methodology, it is also necessary to consider the socio-ecological characteristics of the watercourse. At the same time, environmental characteristics are of priority and limit the operation of SHPPs by the so-called "red lines" with expressions [4-8].

$$Z_{ji}^{upper} = \min \left( Z_{1i}^{max}, Z_{2i}^{max}, \ldots, Z_{li}^{max} \right)$$  \hspace{1cm} (5)

$$Z_{ji}^{lower} = \max \left( Z_{1i}^{min}, Z_{2i}^{min}, \ldots, Z_{li}^{min} \right)$$  \hspace{1cm} (6)

Based on this, electricity generation from small hydroelectric power plants, kW * hour
Fig. 2. Function of SHPP operation

The intersection of the straight-line function to divide the annual work schedule of the SHPP into two stages:

1. $0 - t_1$ – SHPP operates on a watercourse
2. $t_1 - T$ – SHPP operates at rated power.

Based on the above, determine the annual flow through the SHPP by the expression:

$$Q = \int_{0}^{t_1} q \, dt + \int_{t_1}^{T} q \, dt$$

(3)

Annual river flow

$$Q = \int_{0}^{T} q \, dt$$

(4)

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$$Z_{ji} = \max \left( Z_{1i}^{\text{min}}, Z_{2i}^{\text{min}}, \ldots, Z_{li}^{\text{min}} \right)$$

(5)

$$Z_{ji} = \min \left( Z_{1i}^{\text{upper}}, Z_{2i}^{\text{upper}}, \ldots, Z_{li}^{\text{upper}} \right)$$

(6)

$$Z_{ji} = \min \left( Z_{1i}^{\text{lower}}, Z_{2i}^{\text{lower}}, \ldots, Z_{li}^{\text{lower}} \right)$$

(7)

where $H_p$ is measured in m and $Q_p$ – m$^3$

Taking approximately $\eta_g = 7.5$, we get the output

$$W_r = 20.83 \cdot 10^{-4} \cdot H_p Q_{rs}$$

(8)

Thus, the design capacity of a small hydroelectric power station $N_p$ can be taken any, within the maximum to minimum average daily capacity provided by the watercourse. The option is usually guaranteed in which,

$$N_{\text{max}} > N_{\text{guaranteed}} > N_{\text{min}}$$

(9)

As for the second example, a small hydroelectric power plant with a daily regulation reservoir, the water-energy calculations are performed in the same way as shown above, with the only difference in the redistribution of water consumption by the useful volume of the reservoir, taking into account the coverage of the load schedule of consumers in the daily context, i.e. in 24 hours.

$$N_{\text{HPP}} = 9.81 Q_{\text{HPP}} \left( Z_{\text{headwater}} - Z_{\text{tailwater}} - h_{\text{average}} \right) \eta_{\text{HPP}}$$

(10)

$$W_{\text{reservoir}} = \begin{cases} W_{\text{reservoir}} \left( t \right) \\ W_{\text{reservoir}} \left( t-1 \right) \end{cases}$$

$$Z_{\text{head}} = Z_{\text{head}} \left( W_{\text{head}} \right)$$

$$Z_{\text{tail}} = Z_{\text{tail}} \left( Q_{\text{tail}} \right)$$

$$H_{\text{aver}} = W_{\text{head}} \pm \Delta W$$

(11)

where $Z_{\text{head}}, Z_{\text{tail}}$ are elevations of the head and tail of the hydroelectric power station, m; $W_{\text{res}}, W_{\text{res}}(t-1)$ are reservoir volume at the moment $t$ and $(t-1)$, m$^3$; $Q_{\text{tail}}$ is downstream discharge, m$^3$/s; $t_{\text{aver}}$ is depth from the work of the reservoir, m; $t$ is time, s.

The solution to the equation system comes down to comparing water inflow with consumption and redistribution following the load schedule of electricity consumers. It should be noted that in design practice, such calculations are performed in tabular form. This method has been sufficiently developed and improved in many works by different authors and illustrated in technical literature [8-12].

The height of the small hydroelectric power station also affects the output of the rated power. As shown, the operating rate, depending on the height of the SHPP location, the output power is reduced in a linear manner shown in Table 1.

With an increase in altitude, the air becomes more rarefied, and its cooling capacity deteriorates, which will affect the generators of small hydroelectric power plants, mostly with an air-cooling system [13-20].
Table 1. Decrease in the capacity of SHPP depending on the height

| Name SHPP | Marzich | Somon | Vanj | Rushan | Khorog | Namadgut | Ak-Su | Bulunkul |
|-----------|---------|-------|------|--------|--------|----------|-------|----------|
| Height above sea level, m | 1000 | 1288 | 1815 | 1981 | 2075 | 2524 | 3576 | 3744 |
| Power in % of nominal | 100 | 98 | 96 | 94 | 93 | 90 | 86 | 82 |

4 Conclusions

The studies performed in this article have shown that distributed generation based on hydro resources should be selected, taking into account the output of a guaranteed power, which should be significantly overestimated from the height of the generation sources above sea level. This factor is due to the very high altitude of the geographic location of the Republic of Tajikistan, where only 7% of the territory is flat. Simultaneously, for hydroelectric power plants, there is a decrease in the nominal power due to the deterioration of the cooling conditions for generators. The seasonality of small high-mountain rivers is a dynamic system that changes in time with the total generation capacity based on hydro resources, especially considering that the absence of water accumulation in reservoirs will be insufficient.

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