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ISNI: 0000 0004 8495 2390

Dolna 17, Warsaw, Poland 00-773
Tel: +48 226 0 227 03
Email: editorial_office@rsglobal.pl

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AUTHOR(S)	Grigol Khelidze, Teimuraz Bulia, Bachana Pipia
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DETERMINING THE ENERGY EFFICIENCY OF THE RIVER SECTION IN RELATIVE TERMS

Grigol Khelidze
Professor, Georgian Technical University

Teimuraz Bulia
Assistant, Georgian Technical University

Bachana Pipia
Assistant Professor, Georgian Technical University

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ABSTRACT

Electricity production in Georgia heavily relies on the hydropower sector, making it crucial to develop and advance in this area to attain energy independence. Thus, this article presents an opinion on the potential of utilizing Georgia's hydropower resources. The article provides a quantitative criterion for determining the energy efficiency of the river section in relative terms, namely: following the corresponding river fall per unit, length of the river section, and the related water consumption per unit capacity. Accordingly, we will provide a practical example of evaluating a river section's energy efficiency using the mentioned criteria.

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Introduction.

One of the crucial factors for ensuring the sustainable development of Georgia is the development of the energy sector, the primary branch of the economy, in which, from the quantitative ranking of the country's natural resources, hydropower resources occupy a leading position. The hydropower sector plays an essential role in the country's energy production, and progress in this direction in the future is a critical element in achieving the country's energy independence [1, 2]. The development of hydropower includes two issues - one is related to the construction of large hydropower facilities, which are necessary for the normal functioning of the power system because only in this way is it possible to meet the country's demand for electricity at the expense of own hydropower resources. The second is the development of small hydropower and the construction of medium HPPs. Bringing the latter to the forefront was caused by tightening environmental requirements. The construction of mostly medium-capacity hydroelectric power plants with installed 100-200 MW capacity is underway in Georgia. These HPPs are implemented with a derivation scheme. Their reservoirs do not have significant volumes and mirror surfaces. They are equipped with fish hatches and envisage the use of environmental water in the lower beef. As for small-capacity hydropower plants (in Georgia, they include stations with an installed capacity of 15 MW or less [3]), they are being built intensively and at a high pace. It is enough to note that in the last decade, up to 20 small power plants have been launched [4, 5].

The country's electricity demands can only be met by utilizing small hydropower plants. Still, they can improve the quality of energy supply at the regional level and promote the development of the local economy, which ultimately affects the solution of social problems in the country's peripheral areas.

The article proposes utilizing Georgia's hydropower potential in small hydropower development. The authors propose a quantitative criterion for determining the river section's energy efficiency in relative terms: following the corresponding river fall per unit length of the river section $\frac{H}{L}$ and the related water consumption per unit capacity $\frac{Q}{N}$. With these values, it is possible to assess the feasibility of effective energy utilization of the river section concerning other sections at the preliminary design stage with sufficient accuracy. The article discusses an example of determining the energy efficiency of a river section using the mentioned criteria.

At the modern stage, one of the essential elements of ensuring energy security is the reliable operation of small-capacity hydroelectric power stations. In today's world, one crucial aspect of maintaining energy security involves the dependable functioning of small-scale hydroelectric power plants.

Purpose of the study.

When utilizing rivers' small technical hydropower potential, it is necessary to determine the order of arrangement of HPPs, that is, the order of implementation of HPPs. This is a multi-parameter task, which requires considering technical, legal, social, and environmental issues. At the same time, it should be said that at the preliminary stage of designing, when the energy scheme of this or that river is drawn up and, accordingly, the location of prospective HPPs is determined, the primary attention is paid to the use of the energy potential of the river, which is expressed in determining the optimal values of their capacity.

The power of the HPP is essentially determined by the power of its hydro units, in which the power of the hydro-turbine is one of the leading indicators. The latter depends on the turbine system and is calculated by the product of pressure, water consumption, and efficiency of the hydro-turbine. Based on the above, in a specific case, selecting the hydro-turbine type is an essential component of determining the HPP's implementation order.

The main characteristic of a hydroelectric plant is its installed power, which is equal to the sum of the power of all hydroelectric units under their joint operation conditions. It should be noted that the determination of the installed capacity of the HPP as the sum of the capacities of its hydro units is not correct under individual operating conditions since the lower beef level during the operation of a particular unit differs from the lower beef level during the simultaneous process of all units. The specified is reflected in the value of the reference pressure of the HPP and, accordingly, the hydro-turbine. In addition, the reference pressure is affected by the loss in the pressure system, which increases in proportion to the square of the water velocity. Therefore, to determine the installed power at the HPP, the working conditions of hydro-turbines should be considered.

It is known that the following formula determines the capacity of the HPP:

$$N_{\text{HPP}} = 9,81 \cdot \sum_{i=1}^{n} Q_i \cdot H_i \cdot \eta_{\text{tur}} \cdot \eta_{\text{gen}}, \quad (1)$$

where:

Q_i - is the reference water consumption of the hydro-turbine in m^3/s;

H_i - is the hydro-turbine reference pressure, m;

η_{tur} - is the reference efficiency of the hydro-turbine;

η_{gen} - is the reference efficiency of the hydro-generator;

n - is the number of hydro aggregates at the HPP.

It can be seen from equation (1) that two main parameters determine the capacity of the HPP - water consumption and pressure. The efficiency of hydro-turbines and generators can be considered constant under specific conditions for a selected type of hydro-turbine and hydro-generator.

When determining the priority of the construction of the hydroelectric power station, we should be guided mainly by the principle of how much hydropower is concentrated in a particular section of the river. For this purpose, the approach based on determining the energy efficiency of the river section in relative terms is most justified. These values are $\frac{H}{L}$ and $\frac{Q}{N}$, i.e. the fall of the river corresponding to the unit length of the river section and the water consumption corresponding to the unit capacity. Ratio $\frac{H}{L}$ shows us the amount of pressure per unit length, i.e. pressure concentration per unit length, and it is an indicator of effective use of pressure - the higher this ratio, the less length derivation is needed to obtain high pressure, hence the corresponding advantages. Ratio $\frac{Q}{N}$ shows the quantity of water used to get a unit of power, that is, the possibility of rationally using water to obtain a unit of power. This is a significant indicator and can be considered a criterion for efficient energy use of water resources. The magnitude of the mentioned relative characteristics ultimately affects the HPP's energy efficiency and determines its implementation's priority.

These two parameters sufficiently characterize the hydropower potential of a specific section of the river and, therefore, can be used to determine the priority of the HPP arrangement. Naturally, high values of these Ratios determine the HPP's construction sequence.

Of course, in practice, only these values cannot be used to determine the advantage of implementing of this or that HPP compared to other HPPs. When planning a construction project, it is crucial to prioritize the assessment of road and energy infrastructure. This includes analyzing the availability of access roads, power transmission lines, substations, and their overall technical condition. Additionally, it's important to assess the possibility of arranging construction infrastructure such as residential blocks, warehouses, and technoparks. The convenience of access to specific energy nodes should be taken into account.

Research results.

As previously stated, criteria $\frac{H}{L}$ and $\frac{Q}{N}$ are quite suitable for ranking the HPPs in the cascade during the initial design stage while following the preferred construction sequence.

Let's consider a practical example of evaluating the priority of HPP implementation by criteria $\frac{H}{L}$ and $\frac{Q}{N}$.

Let's say we consider a river on which, following the selected scheme, it is determined to utilize it for energy purposes with a 5-step cascade. The values of interest to us for each of the Cascade HPPs are listed below in Table №1.

Table №1.

HPP	The length of the section L, m	Static pressure on the section $H_{st.}$, m	Reference pressure on the section H, m	HPP water consumption Q, m^3/s	HPP capacity kW
I	2000	260	229	1,0	1900
II	2600	360	317	1,4	3700
III	3100	170	150	2,0	2500
IV	2900	110	97	2,9	2300
V	4000	165	145	3,2	3900

When calculating the reference pressure, pressure losses, which amount to 12% of the static pressure, are taken into account. 0.86 is taken as the aggregate efficiency [6].

Following the above data, we can determine the values $\frac{H}{L}$ and $\frac{Q}{N}$ of each HPP, which are given in Table №2.

Table №2.

HPP	$\frac{H}{L}$	$\frac{Q}{N}$
I	0,13	$0{,}52 \cdot 10^{-3}$
II	0,138	$0{,}37 \cdot 10^{-3}$
III	0,05	$0{,}8 \cdot 10^{-3}$
IV	0,038	$0{,}13 \cdot 10^{-2}$
V	0,041	$0{,}82 \cdot 10^{-3}$

Conclusions. As can be seen from the data in Table №2, the construction of cascade hydroelectric power plants should be carried out in the following order: II, I, III, V, and IV.

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