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POSSIBLE SMALL HYDROELECTRIC POWER STATIONS IN THE ARCTIC ZONE

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Abstract

Small rivers of the vast territory of the Republic of Sakha (Yakutia) are poorly studied. In recent years, the interest in their use has increased due to the sharp increase in the cost of the main energy resource of diesel fuel and its delivery to remote areas of the region. Transportation of diesel fuel to remote settlements, depending on the place of delivery, is carried out by rivers or winter roads. At the same time, the republic has significant reserves of hydropower. The potential energy of the small rivers of Yakutia is estimated at about 250 billion kWh*h per year. In the warm season the use of this energy will allow completely replacing the work of existing and future diesel power plants without harmful negative environmental impact. If the cost of environmental protection measures is included in the cost of "standard" energy, the balance pan may well lean towards renewable energy sources. If available, the hydropower resources may provide affordable electricity. Given the high cost of liquid fuel and extremely difficult conditions for its delivery to the Arctic regions of the Republic of Sakha (Yakutia), there are real prerequisites for considering the possibility of creating small hydroelectric power stations.

Keywords: Hydropower resources, river basin, small hydroelectric power station, small rivers, water regime

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1. Introduction

Throughout the Arctic, the isolation of Arctic settlements, as well as the distance between these settlements, complicates infrastructure projects in terms of planning, transportation, implementation, operation and maintenance (Mortensen et al., 2017) Diesel fuel is the main energy resource in most settlements. Transportation of diesel fuel to remote areas also adds a considerable risk, uncertainty and cost of fuel delivery. Currently, the Arctic uses several renewable energy sources with the share of renewable energy sources slightly higher than the global average. Hydropower is the most used renewable energy source. If available, hydropower resources may provide affordable electricity (Witta et al., 2021). In Yakutia, this is caused by an increase in consumption and high costs of delivering diesel fuel to remote areas of the republic. Given the high cost of liquid fuel and the extremely difficult conditions for its delivery to the Arctic regions of the Republic of Sakha (Yakutia), there are real prerequisites for considering the possibility of creating small hydroelectric power stations. The complex transportation in this area requires the search for alternative sources of energy that could reduce the use of liquid fuel, provide interruptions in the operation of diesel power stations for their repair and possible reconstruction (Lipich & Balahura, 2024; Regnerová et al., 2024; Shumilina & Antsiferova, 2024). One of the solutions is the use of renewable hydropower resources of small rivers, the quantitative and qualitative accounting of which is the basis for the selection and placement of small hydroelectric power stations with capacities corresponding to the specific needs of settlements or enterprises with a seasonal nature of work (Ahmad et al., 2024; Singh et al., 2024; Waite, 2024).

2. Problem Statement

Small hydropower plants are attractive from the point of view of environmental protection. In isolated power supply zones they are designed to supply power to individual consumers or to work in local power systems, the load schedules of which practically determine the mode and parameters of such hydroelectric power stations.

3. Research Questions

Regional topographic maps and results of expeditionary studies were used to select the estimated parameters of potential energy of small rivers. Stock materials and literary sources were used.

4. Purpose of the Study

The paper considers in more detail the small rivers of the Indigirka River basin. The hydrological area is poorly studied. The main hydrological posts are located on the Indigirka River itself.

5. Research Methods

The monitoring of the hydrological regime of water bodies located on the territory of the Republic of Sakha (Yakutia) is under the jurisdiction of the Yakut Directorate for Hydrometeorology and

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Environmental Monitoring (Hydrology). Currently, it operates 16 hydrological posts on the Indigirka River and its tributaries (Table 01).

Table 1. Operational hydrological posts (as of 2018)

n/n	Water object-hydrological post	Distance from the mouth, km	Watershed area, km^2
1	Suntar River – mouth of the Sakharynya River	21	7680
2	Sakharynya River – 0.2 km from the mouth	0.2	84.4
3	Agayakan River – Agayakan hydrological post	0.2	7630
4	Elgi River – 5.0 km above the mouth of the Artyk-Yuryakh River	42	17600
5	Artyk-Yuryakh River – 3.5 km from the mouth	3.5	644
6	Chaptahai spring – Granite hydrological post	1.5	24.9
7	Ambar-Yuruete (Dunai) River – Rempunkt hydrological post	1	16.6
8	Indigirka River – Oymyakon River	1624	24500
9	Indigirka River – Yurty hydrological post	1527	51100
10	Indigirka River – Indigirsky hydrological post	1412	83500
11	Indigirka River – Ust-Moma hydrological post	1131	157000
12	Nera – Ala-Chubuk hydrological post	65	22300
13	Delyankir – Delyankir hydrological post	0.9	3070
14	Blizhny stream – 0.3 km from the mouth	0.3	23
15	Indigirka River – Belaya Gora hydrological post	604	287000
16	Indigirka River – Chokurdakh hydrological post	187	322000

Note: The table is based on the official website (Automated information system…)

The length of the Indigirka River is 1726 km and the total length, taking into account the Tuora-Yuryakh River, is 1977 km (Indigirka River). The river network of the basin consists of 125,605 watercourses. The total number of rivers with a length of less than 10 km is 122,125. The total area of their watershed is 189 thousand km^2. The density of the channel network varies from 1.2 in the upper reach to 0.2–0.3 km/km^2 in the lower reach. The Indigirka River has a deep dive in mountainous areas. In some sections of the river valley they have a depth of 600–1000 m, on the plateau and elevated plains – 150–300 m.

6. Findings

The average long-term flow rate of the Indigirka River at the Vorontsovo hydrological post (350 km from the sea) according to (Indigirka) is 1600 m^3/s, and the volume of annual water flow is 50.5 km3/year, the drain modulus is 5.21 l/s·km^2, the drain layer is 165 mm. The watershed area area is 305 thousand km^2 (Indigirka). Every year, the Indigirka River carries more than 50 km^3 of water to the East Siberian Sea, which is part of the Arctic Ocean system. Most rivers of the Indigirka River basin are characterized by extremely low runoff in winter up to complete freezing.

In terms of the water regime the Indigirka River refers to rivers with mixed nutrition. In the upper reach of the river, the spring flood is expressed well only in certain years, the summer period is characterized by a continuous fluctuation in levels depending on rain and melting mountain snow,

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glaciers and ice. The main part is rain and meltwater. The summer period accounts for 50% of the annual flow volume, in spring – 32%, in autumn – 15%, and in winter an exceptionally low flow is characteristic up to complete freezing.

The basin of the Indigirka River is located in the area of continuous distribution of permafrost and the formation of huge deposits (Ulakhan-Taryn in the valley of the Moma River – S=90 km^2, ice thickness – 3–8 m).

Figures 1 and 2 show the average annual water flow rate (m3/s) of the Indigirka River basin from 2008 to 2018 for the hydrological posts of Yurty, Ala-Chubuk, Indigirsky, Granite, Rempunkt, along the Sakharynya rivers (mouth, 0.2 km from the mouth), Artyk-Yuryakh (5.0 km above the mouth, 3.5 km from the mouth), as well as the Blizhny stream (0.3 km from the mouth).

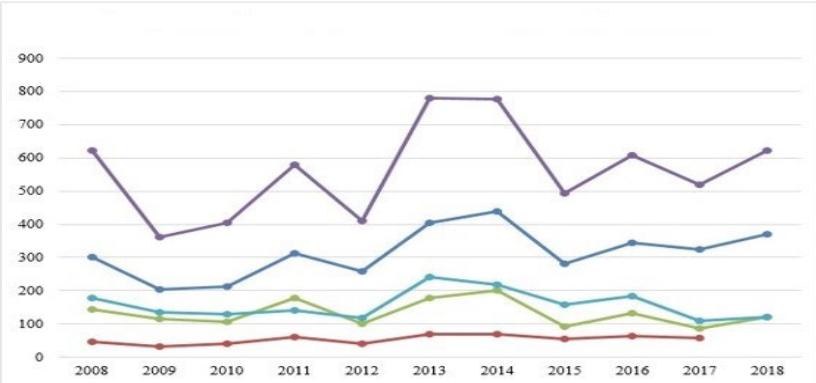

Figure 1. Average annual water flow rate (m^3/s) of the rivers of the Indigirka River basin in the period from 2008 to 2018

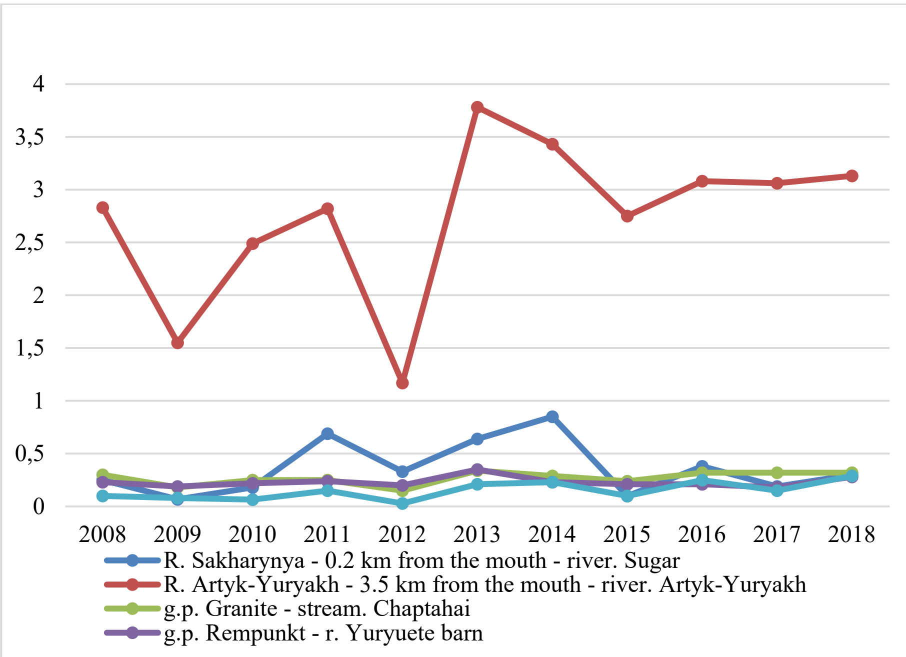

Figure 2. Average annual water flow rate (m^3/s) of the rivers of the Indigirka River basin in the period from 2008 to 2018

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The hydrological study of the northern rivers was most fully carried out on large rivers. Small rivers belong to unexplored objects. As a result, it is difficult to determine the hydropower potential of small watercourses. In 2016, the reliable information about the hydrological regime of small rivers in Verkhoyansky, Tomponsky, Kobyaysky districts was received based on the results of expeditionary exploratory surveys of small rivers of the Yana River basin and the installed capacities of small seasonal hydroelectric power stations for power supply to remote isolated settlements in places of compact residence of indigenous small peoples of the North were considered (Nogovitsyn et al., 2017). The Olenek River has the possibility of considering small hydroelectric power plants on the Kengede River with sufficient capacity and production for power supply of Olenek and Kharyyalakh villages. The Yana basin, where hydrological and high-altitude conditions are quite favorable has great opportunities for the construction of small hydroelectric power plants (Dokuchayeva et al., 2024; Tang & Yang, 2024).

According to the study (Konstantinov, 2014), the Indigirka River basin is divided into 4 districts, according to which the hydropower reserves of the river are estimated. According to (Konstantinov, 2014), huge reserves of hydropower potential of small rivers are accumulated in the mountainous part of the river basin. So, in the first district, the potential capacity of the rivers was 1.4 million kW*h or 12.1 billion kWh*h, in the second – 2.3 million kW*h or 20.4 billion kW*h, respectively.

The total potential capacity of all small rivers of the Indigirka River basin (Konstantinov, 2014; Nogovitsyn et al., 2011) was 4.7 million kW*h or 41.5 billion kW*h of energy in the middle water year.

The development of hydropower resources may, as a rule, be selective, since the construction of a small hydroelectric power station can be envisaged only in places most difficult for the annual transportation of fuel. Besides, not all settlements of the Arctic zone of Yakutia have good opportunities for using the energy of small rivers.

The choice of a potential site for the construction of small hydroelectric power plants in the territory of the Indigirka River basin mainly depends on the volume of river runoff in the warm season, the rush of a current and environmental consequences. In this case, as a rule, environmental and ethnological expertise should be taken into account, as well as the location of specially protected natural areas (protected zones).

The characteristic of small hydroelectric power plants in the specific conditions of the Far North is its seasonality. Therefore, in remote areas the capacity of small hydropower plants is considered as a backup. For uninterrupted supply of electricity in winter, there must be a main source of electricity generation. Thus, the type of power source under consideration may help to optimize the supply of liquid fuel without completely excluding the use of conventional energy fuels (Table 02).

Table 2. Possible seasonal small hydroelectric power stations in the northern regions of the Republic of Sakha (Yakutia)

Settlement, nomad camp	**Indended capacity of small hydroelectric power plants, kW**	**River, water reservoir**	**Alinement place**	**Average consumption, m3/sec**
Sasyr Momsky	250	Moma	374 km from the mouth	181.2
Kyusyur Bulunsky	700	Ebitiem (Eremeika)	1 km from the mouth	2.1

Yurung-Khaya Anabarsky	260	Kharabyl	2 km from the mouth	12.0
Yurung-Khaya Anabarsky	260	Kumakh-Sala, Kennyues stream	0.5 km from the mouth	1.4
Taimylyr Bulunsky	290	Ulakhan Taimyylyyr	1.0 km from the mouth	2.5

According to the study (Nogovitsyn et al., 2017), the only possible place for the construction of small hydroelectric power plants in the Allaikhovsky district is on the Taidah River (right tributary of the Indigirka River), near Olenegorsk village with a capacity of about 50 kW. In the Abyisky district, the option of building small hydroelectric power plants on the Suturuokha River is particularly interesting; its capacity is able to provide electricity to the settlement of the same name and the district center Belaya Gora. There are 6 potential hydrological dams with significant hydropower resources for the construction of small hydroelectric power plants in the Oymyakonsky district (Nogovitsyn et al., 2017).

7. Conclusion

The development of available mineral resources of the Arctic zone of Yakutia is accompanied by an increasing impact on the natural environment. Extremely harsh natural and climatic conditions require environmental policies and principles that ensure that the environment remains balanced.

In order to utilize the hydropower capacity of small rivers in remote decentralized areas, a set of studies should be carried out in specific localities, thus achieving the cost-saving effect of transporting diesel fuel.

There is no experience with small watercourses using micro and small hydroelectric power stations in the Arctic zone of the Republic of Sakha (Yakutia). The main problem of implementing such projects is difficult climatic conditions: with a winter period of about seven months, the operation of the stations becomes seasonal, energy production is significantly reduced or completely stopped. The high cost of 1 kW of power for small hydroelectric power plants, taking into account the underdeveloped transport infrastructure, limits their use. Despite this, with the existing level of knowledge of the hydropower reserves of the small rivers of the northern territories, the use of their energy for small hydropower plants would serve as a source of seasonal alternative electricity in addition to existing diesel power plants.

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