Expected changes of the total hydroenergy potential for the rivers on the right bank of the Pripyat basin based on the flow fluctuations forecasts

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SUMMARY

The total (theoretical) hydropower potential was defined as the total theoretical sum of river runoff energy, which is calculated as the arithmetic sum of potentials in the river sections from the initial / source to the outlet of the catchment (linear estimation method).
The determination of the total hydropower potential consisted of several stages and was carried out using GIS technologies. The general hydropower potential of the Pripyat rivers along all lengths, its right-bank tributaries and for their catchments, in general, is calculated.
To forecast changes of the total hydropower potential, the results of forecasting changes in flow fluctuations were evaluated. The results of research of two different independent methods of forecasting river flow fluctuations are analyzed: forecast of flow changes under the influence of climate change in the near future until 2040 (water balance method) and forecast estimates of flow changes according to stochastic patterns of long-term water flow fluctuations.
As a result, the quantitative values changes of the total hydropower potential in the high-water and low-water phases (based on stochastic patterns) and for the period 2011-2040 (for the water-balanced model) were determined.

Introduction

Recently, the use of river energy is gaining environmental and social significance and may in some way in some way solve the problem of providing the population and businesses with electricity (by building small hydropower plants). To do this, it is important to assess possible changes in the overall hydropower potential of rivers in the near future.

Method and Theory

The total (theoretical) hydropower potential was defined as the total theoretical sum of river runoff energy, which is calculated as the arithmetic sum of potentials in the river sections from the initial / source to the outlet of the catchment (linear estimation method) (Palamarchuk, 2001; Obodovskyi et al., 2016). The definition of the total hydropower potential consisted of several stages and was carried out using GIS technologies (Obodovskyi et al., 2017, 2019a, 2020a).

Results of investigations

The results of the calculation of the THP of the main rivers of the Pripyat basin are presented in Fig. 1 and Table 1. It is 241557 kW (241.6 MW), of which 29.6% (or 99435 kW) is the hydropower potential of the Pripyat River (together with the Belarusian part). Such watercourses characterize significant hydropower potential as the Goryn River (within Ukraine) 32259 kW (9.6%), the Sluch River 26844 kW (7.99%), the Styr River (within Ukraine) 21300 (6.34%)), the river Uzh 11290 kW (3.36%) (Obodovskyi et al., 2019 a,b, 2020 a,b).

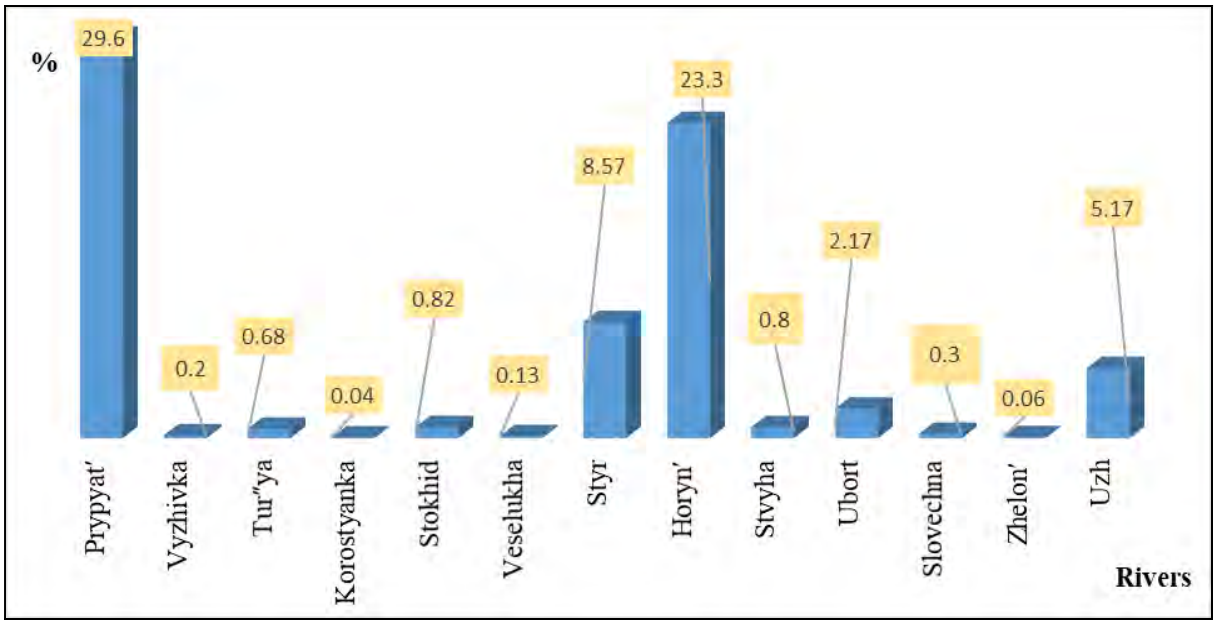

Figure 1 *Characteristics of the total hydropower potential (THP) of the rivers of the right bank of the Pripyat basin by sub-basins as a percentage (%) of the total THP of the right bank of the Pripyat basin*

According to the mathematical structure, the formula of hydropower potential consists of two quantities (acceleration of free fall - g and hydraulic pressure - ΔH), which do not change with time. This formula also includes the value of water runoff, which is characterized by a certain variability over time. Based on this, to predict changes in the total hydropower potential, it is necessary to anticipate changes in water content (Obodovskyi et al., 2016).

We analyzed the results of research by scientists who predicted runoff changes by two different forecasting approaches, namely the forecast of runoff changes under the influence of climate change in the near future until 2040 (Snizhko et al., 2014) and the forecast of runoff changes by stochastic patterns long-term fluctuations of water runoff (Lukyanets and Moskalenko, 2017).
Based on this, the quantitative values of changes of the total hydropower potential for the high-water and low-water phases (based on stochastic patterns) and for the period 2011-2040 (according to the water-balance model) were calculated. (Table 1).

Table 1 *- Indicators of the total hydropower potential of the rivers of the right-bank part of the Pripyat basin under current runoff conditions and forecast values for the high-water phase, low-water phase and for the runoff period 2011-2040*

River	multi-annual mean THP	forecast values for the high-water phase		forecast values for the low-water phase		forecast values for period 2011-2040	
	E_{THP}, kW	E_{THP}, kW	Changes of THP in relation to modern conditions, %	E_{THP}, kW	Changes of THP in relation to modern conditions, %	$E_{ЗГП}$, кВт	Changes of THP in relation to modern conditions, %
1	2	4	6	7	9	10	12
Prypyat′	99435	111172	11.8	81148	-18.4	68 156	-31.5
Vyzhivka	683	779	14.1	545	-20.3	552	-19.2
Tur″ya	2274	2579	13.4	1825	-19.8	1 757	-22.7
Korostyanka	140	158	13	113	-19.4	105	-25.1
Stokhid	2752	3095	12.5	2230	-19	1 985	-27.9
Veselukha	445	502	12.9	359	-19.4	333	-25.2
Styr	28823	32481	12.7	23303	-19.1	21 153	-26.6
Horyn′	78406	88467	12.8	63299	-19.3	58 132	-25.9
Stvyha	2681	3042	13.5	2150	-19.8	2 079	-22.4
Ubort	7300	8253	13	5880	-19.5	5 499	-24.7
Slovechna	1018	1201	18.1	776	-23.7	1 043	2.5
Zhelon′	218	262	20.6	161	-25.9	253	16.3
Uzh	17383	19614	12.8	14033	-19.3	12 891	-25.8
Σ THP	**241 557**	**271 608**	**12.4**	**195 823**	**-18.9**	**173 939**	**-28**

According to estimates of river water forecasting based on water runoff forecasting data taking into account climate change (by to the water balance model) in the near future (2011-2040) a significant decrease in water runoff is expected. This period coincides with the time interval 2010-2020 ÷ 21, in which there is a trend of low-water phase (Snizhko et al., 2014; Lukyanets and Moskalenko, 2017).
According to the forecast of water runoff, taking into account climate change (by to the water-balance model), changes of the hydropower potential of rivers are mainly expected to reduce for the studied basin. This decrease is from 19,2 to 31,5% of the multi-annual value THP for catchments of the study

basin. On average, for the rivers of the Pripyat basin within Ukraine the value of the total hydropower potential will decrease by 28% compared to the multi-annual value THP, namely during the period until 2040 the THP values for the rivers of the Pripyat basin within Ukraine are expected decrease by 67.6 MW. The expected estimated hydropower potential for the rivers on the right bank of the Pripyat is 174 thousand MW. For the Slovechna and Zhelon catchments is a possible increase in the values of THP by 25 and 35 kW, respectively (2,5 and 16,5%). (Table 1, Fig. 2).

During the low-water phase (2010-2020 ÷ 21) according to the results of prognostic assessment of water changes by to stochastic patterns of long-term fluctuations of water runoff, THP for rivers of the Right Bank of Pripyat there is a tendency to reduce THP by 18.9% (45.7 MW), and it will be 195,823 kW (192.8 MW). The total hydropower potential of the Pripyat River during the low-water phase will decrease by 18.3 MW (-18.4%) (Table 1). The largest decrease in water runoff and, respectively, THP in the Pripyat basin is expected on the rivers of the Slovechna (-23.7%) and Zhelon (-25.9%) basins, but according to runoff forecasts using the water balance model, the THP for the rivers of these basins increases in period 2011-2040 (Table 1, Fig. 2).

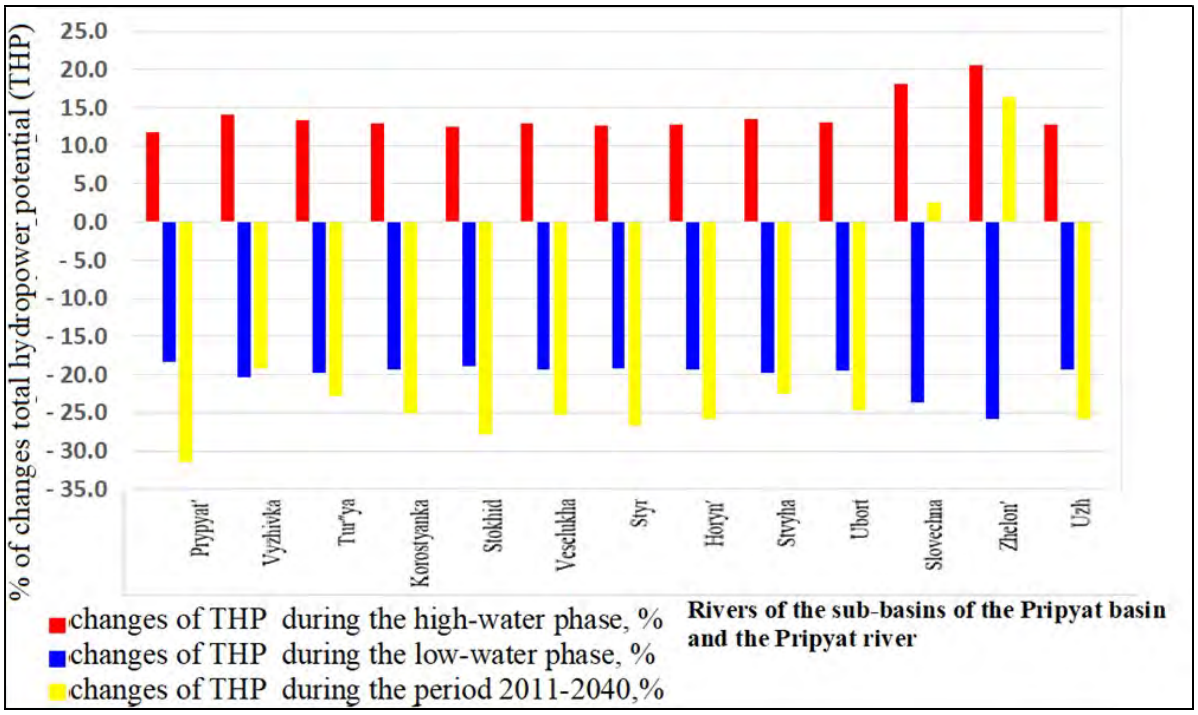

Figure 2 *Relative changes in the forecast indicators of the total hydropower potential (GWP) of the rivers of the right-bank part of the Pripyat basin (within Ukraine) and the Pripyat River*

According to the projected estimates of quality changes for stochastic patterns of long-term quantities of water runoff, the low-water phase of water resources, which changes during the period 2010-2020 ÷ 21 years, is expected in 2038-2048 ÷ 49 years. However, in the period 2038-2048÷49 years are expected and respond to the reduction of the total hydropower potential of rivers after in relation to multi average values.

Periods of high-water runoff for the rivers of the right-bank part of Pripyat are expected in the time interval 2010-2020 ÷ 21 and 2038-2048 ÷ 49. According to the results of the forecast of water changes for this period (2021-2037 (38) the projected indicators of THP of rivers The right bank of the Pripyat will increase by 12.4%, i.e. by 30.1 MW. At the same time, the total THP of the rivers of the Pripyat basin together with the river Pripyat will be 271068 kW (271.1 MW) (Table 1). In the

basin of the Pripyat River, the THP of the rivers of the Zhelon Basin will increase the most during the high-water phase (20.6%).

Conclusions

Assessment of the total hydropower potential changes is necessary for the development of long-term plans for hydropower production, which allows assessing the magnitude and direction (increase or decrease of potential) of likely changes in hydropower capacity of watercourses under the influence of water fluctuations. On average, Pripyat right-bank rivers are expected to increase by 12.4% during the high-water phase and to decrease by 18.9% during the low-water phase. For the period up to 2040, the values of THP for the studied basin will be lower than the multi-annual mean value by 28%.

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