THE ENERGY OF SEA TIDES IN THE CONTEXT OF SOLVING CLIMATE PROBLEMS

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ABSTRACT

The article presents an overview of the technical, economic, and environmental arguments in favour of wider use of the gigantic energy potential of sea tides to solve the most important climate problem today – the reduction of anthropogenic pollution of the Earth's atmosphere with carbon dioxide.

The main idea of the considered solution is the replacement of carbon fuels for thermal power plants and transport with "green" hydrogen. The production of such hydrogen is carried out by electrolysis using the energy of carbon–free renewable sources.

Tidal hydroelectric power plants are the cheapest, largest and most economically safe electricity supplier for the production of green hydrogen today. Until now, this direction of the energy sector has not become widespread due to the high capital intensity, as well as due to the geographic remoteness of the places where tidal energy is concentrated from large centres of electricity consumption.

The explosive growth in global hydrogen demand in recent years alleviates the problem of very expensive transport and large losses in long distance transmission of electricity. Hydrogen can be transported without loss and relatively cheaply by pipelines and sea tankers over unlimited distances.

The use of the energy of the highest tides and flow in the Pacific Ocean for the production of "green" hydrogen is proposed in the revived project of construction of the world's largest Penzhinsk Tidal Hydroelectric Power Plant (the Sea of Okhotsk' north–east, Russia).

Keywords: *tidal energy in hydrocarbon energy, reducing greenhouse gas emissions, capturing and storing atmospheric carbon dioxide, the world's largest tidal power plant*

INTRODUCTION

The existing international agreements and mechanisms for reducing CO_2 emissions into the atmosphere and the ocean have not yet yielded the expected results, and the growing level of carbon dioxide concentration in the atmosphere and hydrosphere of the Earth is steadily approaching the point of no return. In such conditions, the world community is left with no other alternatives, except for toughening agreements and mechanisms for reducing emissions, as well as forcing

the transition of the world economy from predominantly carbon to hydrogen energy.

The climate summit in Glasgow, scheduled for this fall (2021), is intended to try to solve the first direction of solving climate problems. Further development of the use of carbon–free renewable energy sources (RES) can contribute to solving the second direction of these problems. The still underutilized energy potential of oceanic tides is the core matter of this review.

DISCUSSIONS

More than half a century (since 1961) experience of operating the first tidal hydroelectric power plant (TPP) on the estuary of the Rance River (in Brittany, France) has shown that such plants are one of the most environmentally friendly and cheapest in operation carbon–free energy suppliers. At the same time, the construction of such stations is very costly, and their generation of electricity, with a high monthly and annual stability, is not constant within a day.

Russia has accumulated a significant (albeit, mainly experimental) experience in reducing capital costs in the construction of TPPs due to the production of floating modules of their dams at the factory and in the future – towing these modules already with the equipment installed in them to the places of TPP construction [1].

Orthogonal hydraulic units, highly efficient and cheaper than those currently used in world practice, have been developed and tested in experimental operation. According to the developers of these technologies, this makes it possible to reduce the capital cost of the TPP to 1 thousand US dollars per 1 kW of installed capacity [2] at an actual cost of 2.5 thousand dollars per 1 kW, which was formed during the construction of the largest today the South Korean Sihwa Lake Tidal Power Station (2011). This is a significant opportunity to overcome the most important of the above–mentioned economic barriers in the expansion of TPP construction.

Most recently, the British tidal turbine manufacturer SIMEC Atlantis Energy unveiled its latest development, the 2 MW AR2000 system, which will become the largest tidal turbine with a service life of 25 years, which is another new technological breakthrough in tidal power [3].

The second major economic drawback of the discussed energy generation technology – the intraday unevenness of energy production at tidal power plants – can be compensated by the cooperation of TPPs with other types of generation (solar, wind, nuclear, and even traditional thermal) in territorial power systems.

However, the most effective ways of leveling the intraday unevenness of electricity generation at TPPs today should be considered:

Firstly, the use of their cheap energy for large–scale production of such ecologically perfect fuel for thermal power plants that have not yet exhausted their resource and vehicles with internal combustion engines.

And, secondly, for the capture of excess carbon from the air and sea water, its liquefaction and subsequent burial in deep oceanic trenches. That is a direct solution to one of the most pressing climatic problems – the transfer of some part of excess atmospheric and hydrospheric carbon from its short biosphere cycle (– atmosphere and hydrosphere – biosphere) into a long – geospheric (geological) cycle for many thousands of years. That means, practically forever.

Finally, another important, but now an indirect effect of large–scale production of liquefied hydrogen at TPP can be considered a multidimensional synergistic stimulation of commercial demand for the development of advanced technologies for the production, storage and transportation of this new (possibly exchange-traded) commodity with an inexhaustible raw material base, for a new carbon-free energy and other sectors of the economy of the future, for the formation of wider front in solving climate problems.

According to experts [1], it is possible to construct a TPP with a total capacity of up to 787 GW with an electric power generation of up to 2037 TWh per year in areas favourable for the construction of TPPs on the world's seashore. Including in Russia about 250 TW.

At the same time, only about a dozen TPPs with a total installed capacity of up to 500 MW are still operating in the world. The most powerful of them – Sihwa Lake Tidal Power Plant (254 MW), was commissioned in the Republic of Korea in 2011. Its capacity is only slightly higher than the capacity of the first industrial TPP at the estuary of the Rance River – 240 MW (Brittany, France, 1961) [2].

Two more TPPs with a capacity of 1500 and 800–1300 MW are currently under construction [4]. Thus, the actual use of the available natural potential of cheap and environmentally friendly tidal energy in the world is still very insignificant, despite the long mastered and constantly improving technologies for its production.

Such a seemingly illogical situation for a market economy can be explained by at least three factors:

Such a seemingly illogical situation for a market economy can be explained by at least three factors:

- significantly higher unit capital costs than in the construction of other types of power plants;
- the relative rarity and considerable remoteness of the targets favourable for the construction of TPPs from the existing centres of large–scale electricity consumption. This circumstance additionally increases the total capital costs when using the energy of the tides for the construction of powerful and long power transmission lines from the TPP to consumers;
- as well as the above–mentioned feature of the energy of tides – its intraday irregularity, which implies the need for daily compensation for failures in the generation of electricity from TPPs and, therefore, the need for them to work in tandem with a power plant of another type of corresponding capacity, or to connect to fairly large territorial power systems.

These and some other problems that have hindered the fuller use of the huge potential of tides in the world energy sector until now are being solved today, on the one hand, by the gradual reduction of the capital cost of building a power plant, mentioned above, and on the other hand, by the explosive growth of the world economy's demand for such a universal, environmentally impeccable and urgent energy fuel as hydrogen, which is necessary to solve the escalating climate problems.

According to [5], the annual global production of hydrogen in 2017–2019 was 55–65 million tons, which were consumed mainly in the chemical and oil refining industries. Energy consumption of hydrogen has so far been predominantly experimental in nature.

According to the European Roadmap for the Development of the Hydrogen Economy [6], in 2005 the total energy demand in the EU was about 14,000 TWh, of which 325 TWh (8 million tons) was hydrogen [6].

In the near future, this map considers two scenarios, according to which the supply of hydrogen to the EU market by 2050 should be from 12 to 18 and from 16 to 55 million tons [6].

Other countries of the world are also rapidly build up plans their plans for the production of hydrogen, although quantitatively the forecasts of the annual volume of the hydrogen market by countries sharply differ: from 500–2000 TWh to 2050 [7]. According to other more optimistic estimates, the world's hydrogen production by 2050 could grow to one billion tons per year [8]. At the same time, it is noted that today there is no answer to the question of the availability of energy resources for such a sharp increase in hydrogen production, especially if we bear in mind the "green" hydrogen – hydrogen obtained by electrolysis of water with the help of energy, which excludes the emission of carbon during its production.

It should be noted that the authors of [8] in the latter case express fair doubts. Indeed, modern capacities and structure of electricity generation even in Russia, where the share of electricity generation at thermal power plants in 2020 was already less than 60 % [9] (which is not the worst indicator in the world energy sector). But for the production of "green" hydrogen in Russia, there are still no sufficient reserves of capacity at power plants with carbonree electricity generation technology: hydroelectric power plants, nuclear power plants, wind power plants and solar power plants.

However, a resource that is overlooked in this article [8], is tidal energy potential. It is a major source of carbon-free energy generation for the production of precisely "green" hydrogen, adequate to the economic and environmental requirements.

On the entire Pacific coast of the Earth, this potential has the highest parameters in the Penzhinsk Guba of the Shelikhov Bay (northeastern part of the Sea of Okhotsk) between the territories of the Kamchatka and the Magadan Region of Russia.

The largest tides in the Pacific Ocean occur here – from 9 to 13 meters. Due to an area of the Penzhinsk Bay of about 21 thousand square kilometers, up to 500 cubic kilometers of water moves through its "gate" every day. Here, back in the seventies of the last century in the USSR, it was planned to build the most forceful power plant in the world – the Penzhinsk TPP. Its design capacity during construction in various sections (North or South – see figure 1) was from 21 to 87 GW. Possible annual power generation was expected from 72 up to 200 billion kWh [10].

Fig. 1. *Map diagram of the placement of the Northern and Southern gates of the projected Penzhinsk Tidal Power Plant [11].*

For various reasons, but, first of all, due to the lack of sufficiently large consumers of electricity in the nearby territories, as well as due to the unacceptably high cost of its transportation over long distances, the implementation of this ambitious project was constantly postponed. Only with the emergence of a high market demand for "green" hydrogen, which can be transported without losses through pipelines or tankers, this project got a chance to be implemented.

According to TASS report dated July 13, 2021, «H_2 Clean Energy» company, together with the Kamchatka Territory Development Corporation, has begun to develop an updated project for the construction of the world's largest Penzhinsk Tidal Power Plant in the Sea of Okhotsk. Its capacity is initially supposed to be used primarily for the production of "green" hydrogen [12].

The same company envisages the construction of a hydrogen production plant in Magadan with the aim of exporting it to the countries of the Asia–Pacific region and, together with RUSNANO, they plan to create a hydrogen hub in the Murmansk region, as well as redesign the Mamakan Hydroelectric Power Station in the Irkutsk region for hydrogen production. Thus, Russia has made a serious claim for significant participation in the efforts of the world community to implement the

transition of world energy to a carbon–free foundation, and hence in the practical solution of global climate problems.

Of course, the use of even the entire energy potential of the ebb and flow of the Ocean will not fully provide this transition, which is absolutely necessary for mankind. But in the longer term, improving solar energy technologies will be able to finally close the problem of anthropogenic pollution of the planet's atmosphere with carbon dioxide.

Large tidal power plants similar to the Penzhinsk TPP, working mainly for the production of "green" hydrogen, should help to win the time necessary for such a revolutionary technical solution to the problem.

The authors consider the message of this article in attracting the attention of international organizations designed to solve the problems of negative climate change, as well as the world business community to support this ambitious project in every possible way.

CONCLUSION

In the natural capital of the world economy there is a significant, but so far underutilized energy resource – the tidal energy of the Ocean generated by the gravitational interaction of the Earth, the Moon and the Sun.

Significant in time world experience of using tidal power plants (TPP) has shown their high technical reliability, economic efficiency and environmental safety.

The only technological disadvantage of the PES is the intraday irregularity of electricity generation. In modern conditions, this natural disadvantage of TPPs may not have a negative significance when using the relatively cheap electricity they generate to obtain "green" hydrogen – ecologically perfect fuel for thermal power plants and transport with internal combustion engines. A fuel that can contribute to a fairly rapid (albeit technically difficult) transition of the world economy from predominantly carbon-based energy to a carbon-free one.

Right this transition, together with the energy support of the technical possibility of the excess carbon direct capture from the environment with a purpose of its future disposal, they represent practically the only real prospect for a significant breakthrough in solving the aggravating climate crisis caused by an increase in the concentration of carbon dioxide in the atmosphere and hydrosphere of the Earth.

The implementation of this energy transition can, to a certain extent, could be facilitated by the construction of the world's largest Penzhinsk TPP in the Sea of Okhotsk (Russia), which plans to produce the "green" hydrogen as a core feature of project’s concept. A joint decision to develop a new project for this TPP was made by “H_2 Clean Energy” and JSC “Kamchatka Territory Development Corporation”.

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