ENVIRONMENTAL PROTECTION AND SOCIAL ASPECTS OF TIDAL ENERGY

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Keywords: Water Exchange, Fish, Plankton, Salinity, Ice Regime, Sediments, Bottom communities, Social advantage

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Summary

The year 2000 marks the 32nd anniversary of the experimental operation of an electric power plant, which was pioneered in Russia as a plant utilizing the energy of marine tides - the Kislaya Guba tidal plant on the arctic coast of the Barents Sea; the 30th anniversary of the world’s first commercial TPP - the Rance plant in France - was noted in 1996 at an international scientific and governmental conference.

Both of these constructions, which are unique in terms of type, not only have demonstrated the viability of tidal energy in terms of methods employed for the construction and operation of the electric plant, but have also proven the biological permeability of dams for TPP and the complete ecological safety of TPP.

TPP do not pollute the atmosphere with toxic effluents in contrast to thermal electric plants, do not heat the earth, do not require compensating expenditures for land reclamation, do not threaten with catastrophe due to the breaching of dams, as do HPP, and do not represent any potential risk to humans in contrast to nuclear plants. As proof of the favorable effect of TPP on the ecosystems of TPP basins cut-off from the sea by

dams, it is possible, for example, to cite the opinion expressed by the owners of the land adjacent to the Rance TPP and its basin. While crediting the TPP authorities for the virtues of the project, they also noted marked improvement in the natural setting, transportation and fish breeding, the absence of storm effects within the surface area of the basin, and a significant increase in tourism.

1. Studies of TPP Effect on Environment

It is understood that the ecological purity of a TPP is relative, since its construction and operation, like any of human intrusions in nature, could not remain without repercussions. TPP are distinguished, however, by the fact that these repercussions are minimal as compared with other types of power plants. Moreover they also have positive sides: the creation of favorable recreational conditions; protection of shorelines from wave action; reduction in the turbulence of the water masses and their purification, which is favorable to flora and fauna. The floating method of construction carried out at the Kislaya Guba TPP (see *Tidal Power Plant Equipment*) makes it possible to transfer basic work associated with construction of TPP from an uninhabited region of a readily injured nature to an existing coastal industrialized center, avoid the destructive cessation of water exchange between the basin and sea during construction, while the model for use of a single-basin tidal plant, which has been developed in Russia and gained world-wide recognition, does not disturb the natural rhythm of power generation.

All presently known impacts of a TPP on the environment may be generally summed up as follows:

- Construction of the TPP barrage brings about an inevitable attenuation of the natural water exchange between the bay and the seas by 5÷75% depending on the types of models and regimes;
- Distribution of water velocities in the bay area and seawards of the barrage is changed since the water motion after the bay enclosure occurs only through the water conduits. Because of this, high velocities will be maintained in the area adjacent to the central part of the barrage (the power house), while on the flanks of the water-retaining barrage a substantial decrease in water velocities occurs;
- Attenuation of the water exchange and the alternation in overall hydrodynamic pattern result in the re-distribution of bottom deposits within a wide coastal zone of the bay - just those water area zones that are richest in bottom fauna and flora;
- Restructuring of sediment deposits from conductive to alteration of the major part of the bay ecosystems. The duration of the alteration process is some 10 years. The ecosystems' ability for self-renewal after this period is completely dependent on the TPP operation and this needs to be considered while analyzing the possible impacts of any TPP on the environment;
- Attenuation of water exchange between the TPP basin and the sea enhances the dependence of the water area separated from the sea on the terrestrial processes (fresh water run-off, heat exchange etc.) and reduces its stability. Principally this can result in a certain desalinization of the water body in the process of spring ice melting and in the periods of heavy rainfall in the summer;
- The experience gained during operation of the Rance TPP shows that as the result of attenuation of wave action and decrease of water turbidity in the TPP

basin, mariculture can be successfully developed in the basin. Some ecosystems proved to be richer than before the TPP construction and compared with neighboring estuaries. In addition the protection of the TPP basin against storms favors navigation, aquatic sports and tourism;

- One further consequence of the decrease of water exchange and utilization of a portion of the tide energy is the decrease of the tidal range in the basin; this results in lowering of the tidal level, i.e. degeneration of the exposed zone upper part into a terrestrial biotope;
- Lowering of the upper level of the tide can in turn bring about a change of the ground water level in the lowland territories immediately adjacent to the basin of the future TPP. Under certain conditions this can be detrimental for the vegetation and the ecosystem of marshes;
- The barrage stands in the way of anadromous fish migration. Some of the migrating adult fishes can be injured while passing through the turbines.

2. Assessment of Tidal Barrage Environmental Implications

More detailed ecological studies were carried out during the 35 year period of construction and operation of the Rance TPP in France and the Kislaya Guba TPP in Russia as well as during investigations for planned large Severn TPP in England and the Tugur TPP in Russia.

The influence exerted by a TPP on the environment has been investigated in Russia since 1924 on the initiative of their designer - the S.Ya.Zhuk All-Union Scientific Research Institute for Design and Exploration. Comprehensive study of the natural conditions in the region of the Kislaya Gulf was begun as early as 1938-1939 with investigation of the climatic, hydro-geological, and ice conditions. Studies involving the flora and fauna in the Kislaya Gulf were carried out in the 1960s and 1970s by the Northern Polar Scientific-Research Institute of Sea Fisheries and Oceanography (K.P.Gemp), the Institute of Oceanology, Academy of Sciences of the USSR, and the Murmansk Regional Museum. The Polar Scientific-Research Institute of Sea Fisheries and Oceanography, the Murmansk Higher Nautical School, the trust “Sevryba”, and diving crews of the All-Union Voluntary Society for Assistance to the Army, Air Force and Navy, and others participated in the research during the construction of the TPP and in the first years after it had been placed in service.

A detailed study of the effect of the Kislaya Guba TPP on the environment was initiated in 1983 with participation of the Murmansk Marine Biological Institute, the Polar Institute of Sea Fisheries and Oceanography, the Institute of Biology of the Southern Seas, and the Moscow State University.

In the 1990s extensive field work was carried out in the TPP basin by St-Petersburg scientists within the UN program “The Baltic Seafaring University” (Section “North”) for elaboration of monitoring principles for up-to-date assessment of conditions of ecological systems, sea shore natural and engineering systems and their possible use as the basis for elaboration of management principles for all the northern sea shore zone.

The research that we conducted makes it possible to assess the current ecological situation in the Gulf of Kislaya as quasi-stable on the whole. The species diversity of the benthos and plankton is being maintained at a rather high level. However the formation of the ecosystem in the gulf is apparently still incomplete today. The ecosystem that is being formed differs from the initial one, corresponding to the new conditions.

Species depletion and lower stability as compared with the reference ecosystem of the Gulf of Ura, the dependence on the tidal power plant and preservation of salt-water species can be considered as basic characteristic features of the natural-technical systems of the basin. The littoral (by reason of the possibility of vigorous freshening) and trench depressions (due to oxygen deficit) can be called zones of ecological risk.

It is possible to optimize the ecological situation in the basin of the Kislaya Guba TPP, using a system of engineering-technical measures, including operation of the plant only in a continuous ecologically safer regime.

The creation of a center for marine-culture development at the TPP base is of interest. Hatcheries of an experimental fish farm run by the Polar Scientific-Research Institute of Sea Fisheries and Oceanography, where procedures are being developed for the breeding of rainbow trout, humpbacked salmon, and cod (including the use of planting stock and feed from the “Arctic Salmon” Company) are situated along both sides of the TPP dam. Studies are being conducted here on the adaptation of the Kamchatka crab, the breeding of see anemones in fish hatcheries, and refinement of the procedure employed to collect their roe.

It is suggested that the experience gained with the rapid assessment of the ecological situation in the basin of the Kislaya Guba TPP during the period 1994-1996 might be used for the ecological inspection of projects involving future tidal plants. In particular it can be used as the basis for development of principles for monitoring of marine natural-technical systems in the coastal zone and on the shelf of the Barents Sea.

3. Change of Hydrological Regime at Tidal Barrages

Investigation of the hydrological regime in the basin cut-off by the dam indicated that it depends completely on the regulation of water exchange. With free water exchange, the fluctuation of the level in the basin repeats the fluctuation of the level of the sea on the whole, but with a smaller swing (1-2 m) and phase shift (2-3 h). The reduction in water exchange may amount to 1/3 and more of the natural rate, depending on the construction and the operating regime of the TPP. At the Kislaya Guba TPP, the basin of which has a narrow inlet and a dam with only one hydraulic-generating set, water exchange is reduced even in the special “basin-flushing” mode, and is five times lower in the mode designed for the generation of electric power as compared with the natural regime. At the Tugur TPP, which will be constructed in a large bay open to the sea, water exchange will diminish by only 39% for the optimal mode of electric-power generation.

Reduction in water exchange cannot be specified only as negative. In those cases when the maximum velocity of the water prior to construction of the plant exceeds 2 m s^{-1}, its reduction will contribute to the possibility of the existence of bottom communities that are more diverse with respect to composition and richer with respect to biomass. Moreover, a reduction in water exchange and a change in the overall pattern of the hydrodynamics will lead to redistribution of bottom deposits in the shallow zone, which will be populated to a greater degree by bottom fauna and flora. Thus, the fractional and chemical composition of the solid sediments, together with the water temperature, is determining for the distribution of bottom organisms throughout the biotopes.

Even a negligible change in the composition of sediments on the bottom within the limits of a thin surface layer can essentially disrupt the viability of numerous burrowing organisms composing the majority of the bottom ecosystems. Under estuarial conditions characterized by large volumes of incoming suspended material, appreciable depositions of bottom sediments and their accumulation may restrict navigation and even influence electric power generation.

Deposits of bottom sediments will lead to rebuilding of the bottom ecosystem of the bay, the duration of ecological rebuilding will amount to more than 10 years after construction of TPP. The dynamic equilibrium established after this time in the renewal of the ecosystems will depend entirely on the operating regime of the TPP; this must be considered in analyzing the ecological consequences of the implementation of any project.

The reduction in water exchange should reduce the water turbidity; this may ultimately exert a positive influence on the productivity of the pelagic bottom ecosystem. This argument has been frequently used in substantiating the expediency of designs for the Severn, Mersey, and other TPP located at the mouths of rivers carrying a large amount of nutrients for bottom flora and fauna.

A reduction in the amplitude of water-level fluctuations in the basin, which result in regeneration of the upper portion of the drainage strip, is also a consequence of reduced water exchange and the tapping of a portion of the tidal energy. According to expert evaluations, the productivity of the remaining drainage zone (littoral) should increase considerably as the area of the drainage zone decreases after TPP construction.

A drop of the upper tidal boundary can manifest itself over time as a change in the water table in the area directly adjacent to the basin; this should be considered in designing TPP in addition to characteristic features of coastal land ecosystems.

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Biographical Sketch

Igor N. Usachev was born on July 4, 1932, Moscow, USSR

1957 – Graduated from the Moscow Power Engineering Institute.

1973 – Candidate of Technical Sciences (Thesis Investigations of very high frost concrete and fine-wall reinforced concrete hydraulic structures at the North.

1957 – up to now – engineer, chief engineer of the projects, Director of Laboratory and Head of Department, Design, Survey and Scientific Research Institute «Hydroproject».

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