ECONOMIC ASPECTS OF TIDAL ENERGY

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Summary

Renewable, ecologically benign and monthly dependable energy of TPP, available in the power grid is at the same time the cheapest energy as compared to energy prices of all the other existing at present power stations: thermal, nuclear and hydro. There is a tendency of cost divergence in the course of time between the cost of TPP energy and the cost of energy of any other power station in favor of TPP. This cardinal advantage of TPP in modern power grids has been proved by 30 year operation of the Rance TPP, France, the first commercial tidal power plant in the world.

At the same time, due to new technologies and equipment, tested in recent decades, capital costs and construction period of TPP are actually equal to those of hydro power plants, according to the data of recent large projects in Russia and England.

Besides there is still an unused reserve for reducing TPP price, i.e. economic effect of TPP ecological purity as compared to thermal and nuclear power plants.

1. Reasons for Rise in the Cost of TPP Construction (Historical Background)

The first and the main obstacle for TPP designers turned out to be daily irregularity and intermittence of tidal energy.

It took the experts 250 years to solve this problem. Nearly all the world famous engineers were solving the problem of tidal energy non-regularity by dividing the TPP basin into 2, 3, 4, etc. parts with separate dams, each with its own units. Due to this, more or less uniform distribution of energy throughout the day was reached. But in doing so it was neglected that one and the same quantity of tidal energy required 2, 3, 4, etc. times as much capital costs for construction of duplicating dams. Therefore all the started constructions of double-pool TPPs were stopped as they turned to be more expensive than similar thermal power plants. Thus in 1929 construction of the Aber-Vrak TPP in France was stopped for this reason. At the same time in France there appeared the ideas about TPP operation combined with the work of both thermal and hydro power stations. Unfortunately these were only ideas, which have not been realized and development of multi-pool TPPs continued in the world up to the middle of XX century.

In the USA the designing of the TPP in Passamaquoddy Bay, where the highest tides are observed, received primary emphasis. A double-pool TPP with 3 billion kWh annual output was offered in Cooper's design in 1921, and in 1936 a single-basin operating model of TPP with 0.3 billion kWh annual output was proposed. The implementation of the last design, financed by the USA government from the Unemployment fund was also stopped, as the cost of its energy of about 1 cent per 1 kWh occurred to be much higher than energy costs of hydro and thermal power plants at that time (0.2-0.6) US cents.

In spite of the already paid expenses of nearly US$ 50 million, the construction was frozen and 4700 workers were deployed. However, designing of the TPP in Passamaquoddy Bay continued and only at the beginning of 1950s the Canadian and US governmental commissions found the project to be cost-ineffective.

Last time the project was reactivated in 1963-1964. The TPP capacity was brought to 1.8 million kW; installation of bulb units was proposed, which meant progress for TPP. Unfortunately, again due to double-pool design, capital costs of TPP construction were 2.8 times as much as those of HPP.

The argument about multi-pool TPP seemed to be settled in Russia during the period 1967-1973, when L.Bernshtein during studies and designing of the Lumbovskaya TPP on the White Sea rejected a double-pool model and proved its disadvantages (duplicating power sources and additional expenditures for the second dam).

2. Inefficiency of Traditional Technology of TPP Construction behind Cofferdams

At construction of the Rance TPP, the first commercial TPP in the world, the most complicated problem was construction of cofferdam in the sea (see Figure 1). This unique sea cofferdam of complicated design actually threatened the construction of the TPP as is required one sixth of the construction cost. Mainly due to the use of traditional construction technique capital investments for the installed 1 kW of the Rance TPP were double the price of HPP of similar capacity.

In 1963 L.Bernshtein proposed and used the caisson method for construction of the Kislaya Guba TPP in the Barents Sea in Russia. This now well-known method was used for the first time in hydraulic engineering. Its usage permitted cardinal reduction (by more than one third) of capital costs for construction of the TPP.

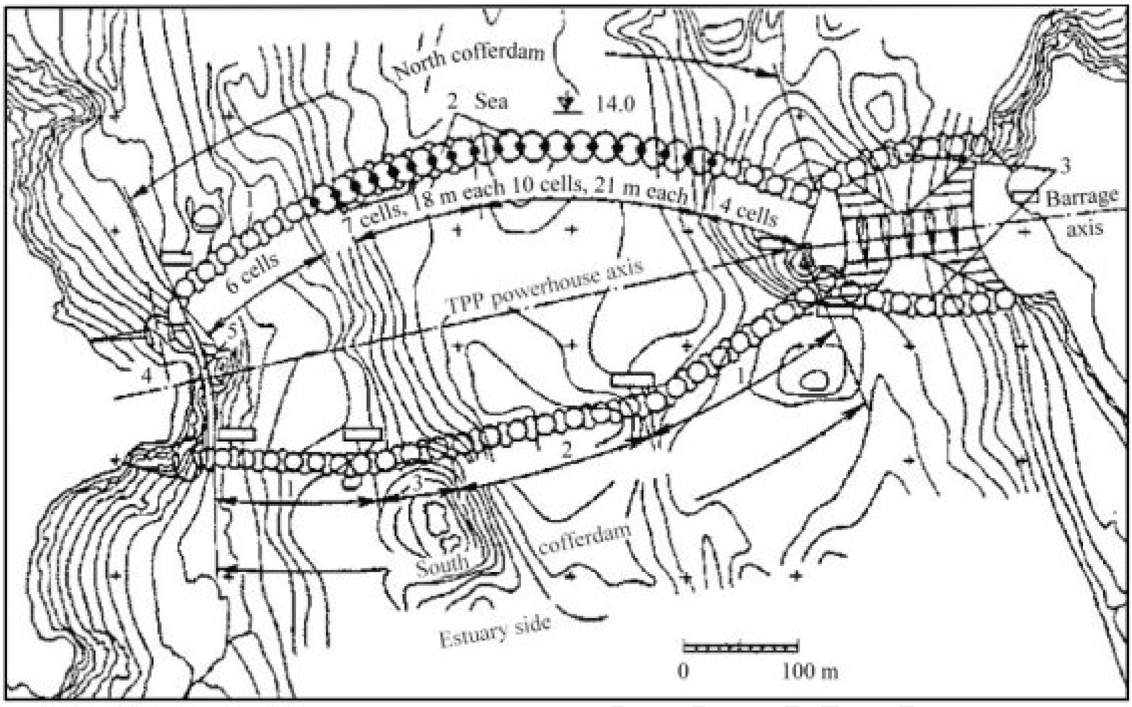

Figure 1. Plan of cofferdams:
1 - sheet-pile cells 19 m in diameter; 2 - sheet-pile cells 21 m in diameter supported by reinforced-concrete columns; 3 - cellular cofferdam; 4 - lock pit; 5 - concrete cofferdam with crest elevation of +7 m (construction data of the Rance TPP).

3. Possibilities of Significant Reduction of TPP Costs, Using New Equipment

TPP separates basins from the sea by long barrages (up to 100 km), incorporating hundreds of hydro turbines.

At existing modern TPPs and low head HPPs all over the world axial turbines are installed. Several decades of operation and studies permitted improvement of axial turbines to a high extent, but they are expensive and complicated, moreover, they can be manufactured only by special turbine manufacturing works. Therefore manufacturing of hundreds of units even for one large TPP can increase construction period to indefinitely great extent and lead to multi-fold increase of cost.

In 1985-1989 searches for new mechanical and electrical equipment for TPP led to renewal of studies of cross-flow (orthogonal) turbines with rectilinear wing-shaped blades. Those turbines are a variety of Darrieus rotor (See *Wind Energy*). Investigations were abandoned, as their efficiency was less than 40%.

However, in Russia, the efficiency of the orthogonal turbine was brought to 75% by modifying configuration of the turbine chamber and the blade system and its feasibility was proved for the installation at TPPs (and small HPPs), if reverse operation was provided.

The main advantages of orthogonal turbines in comparison with axial turbines are as follows:

- Reduction of mass (cost) up to 50%;
- Increase by 2.3 times of waste releases through the turbine, allowing reduce of over-flow dam size;
- Facilitation of the streamline commercial fabrication of orthogonal turbines not only at turbine manufacturing works, but at any metallurgical works.

Design of 11.4 GW Mezen TPP, Russia (1999), showed that 600 orthogonal turbines can be manufactured during only 6 years and the first units can be commissioned on the 8th year of construction, thus reducing total cost of TPP by 18%. Actual use of orthogonal units seemed to solve the previously unrealizable problem of delivery to TPP a large number of units during short construction period.

4. Cost-Effectiveness of TPP

It is evident that cost-effectiveness of TPP first of all depends on the value of the tide and area of the separated basin. Water discharge through TPP determines its main parameters and it can be estimated from the barrage length, where hydro units are installed.

Most fully cost dependence (unit cost per 1 installed kW) was determined in England from the projects off 22 TPPs and in particular from more detailed projects of Mersey and Severn TPPs. Engineering companies obtained the dependence of 1 kWh (in pence) cost, on mean value of tide, basin area, length and height of the barrage:

$$\log U = K \cdot \log\left[\frac{L^{0.8}(h+2)^2}{S(A_m-1)^2}\right]$$

This formula permits determination of the most cost-effective variants for site selection and tidal barrage parameters.

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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».

1963-1984 **–** Chief of Group on Working Designing and studies of Hydroproject, Kislaya Guba tidal power plant/

Author of more than 400 scientific papers and 7 monographs.

Main activities: mastering tidal energy; introduction of floating techniques in erecting of hydropower projects; development of long-lasting marine construction materials; electro-chemical and biological corrosion protection.

Member of Scientific Council on Biological Damages of the Russian Academy of Sciences.