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POWER FROM ARCTIC WATERS*

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ABSTRACT

An extended abstract of part of this paper was presented at the International Polar Year (IPY) Conference that took place in Oslo, Norway June 8-12, 2010. The present text is the complete version. It aims to confirm that ocean energies can be successfully tapped in polar environments and contribute to energy production and sustainable development of Nordic regions.

Harnessing ocean waves has been proven possible and if such a scheme was decommissioned after some six years of operation the cause lies only with a storm of exceptional intensity. Lessons have been learned to lessen their impact. What may well remain an engineer's dream is a scheme which may have a foundation in the OTEC ideas. Marine winds have not been tapped at these high latitudes in any significant manner, but may hold reasonable promise.

Tidal energy has been used for centuries with both tidal current and rise and fall of tides put to work. They provided power for flour mills, saw mills, breweries etc. Their mills dotted several geographic areas regions of Europe from The Netherlands to Spain and from Wales to England, but also coastal areas of the United States and Canada and may be viewed as the forerunners of the power-generating tidal power stations. Utilizing the tidal processes has received considerable attention during the last few years as oil reserves, oil prices, climate changes cause increasing concern. China is considering building a plant and Korea (R.O.K.) has undertaken the construction of the largest ever tidal power station.

KEY-WORDS: tidal energy, power plants, electricity production

INTRODUCTION

Ocean energies, as it has been proven, can be put to work in polar regions (Charlier & Justus, 1993). A wave harnessing scheme has functioned for six years until a particularly severe storm put it out of commission. In the Russian Arctic and in Norway, tidal power facilities provide electricity albeit modestly. The Kislaya Guba (Russia) plant has received new turbines and further expansion is being undertaken. Marine winds could conceivably be tapped and even temperature difference exploited.

Try-outs of calling Neptune, or Poseidon, to the rescue in the polar regions may not be far fetched; as a matter of fact, try-outs proved quite successful (Fry, 2005).

An allegoric image may well show trident-brandishing Olympian Neptune, his foaming beard flowing to the wind, erect on his fish-fins toes nostrils-fuming horses-pulled chariot, reins let loose, rushing to the rescue of humanity that placed planet Earth, or is it planet Ocean into jeopardy by an unquenchable thirst for energy, not even sated at the cost of bringing about climate chaos (Fig. 1).

Fig. 1. Neptune to the rescue! (excerpt - detail - from a ceiling painting in Washington DC)

TIDAL POWER

The only tidal power plant in the Arctic had been the Russian facility near Murmansk, until at Hammerfest a tidal scheme was put to work. The Kislaya central (Fig. 2) celebrated its 40th anniversary and has proven that a tidal plant can function - and last - in the Arctic and that it can replace fossil fuel facilities, that costs of construction and maintenance (as compared to its model on the Rance River) can be cut, and even… can be built by an exclusively female team! (Chaineux & Charlier, 2008).

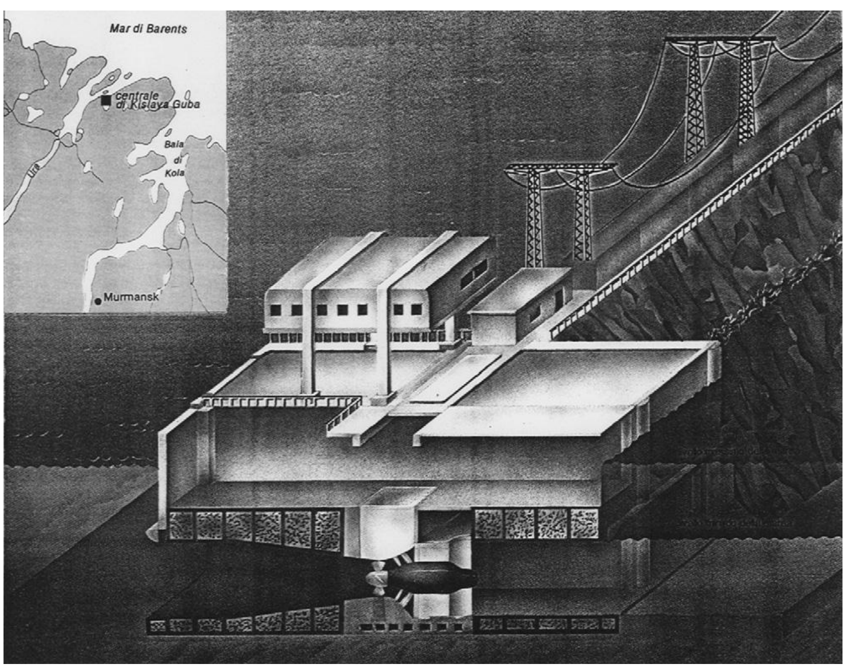


Fig. 2. Location map and stylized picture of Kislaya Power Station (drawing from Ed. Fabbri, Milano). View of the bulb turbine of the plant; it is of the same type used in the French Rance River tidal power station linked to the grid

THE KISLAYA BAY PLANT

The Kislaya plant is sited close to the White Sea with its potential of 16 million kW. Built on a narrow inlet, only 40 m wide and 3-5m deep, wherethrough water gushes at high tide at a speed of 4m/s. Its dam takes advantage of the narrow squeezed between 40 m high cliffs. The water depth is 35 m and the water surface 1.1 km^2. The average tidal amplitude is 2.5 m. The site was prepared by removing rock by underwater blasting and loose rock removal, using a clam-shell-type crane. An excavation of some 25,000 m^3 was thus created. Next a sand-and-gravel bed was put in place. Kislaya Guba on the Barents Sea has 0.5 MW installed capacity. About its 40^{th} anniversary (2006) it was upgraded with a 1.2 MW experimental advanced orthogonal turbine. Further expansion has been decided upon and may have been initiated.

All in all, and allowing for the different climatic conditions (ET type in Murmansk area), there are many differences between the Rance River, that served as the basic model, and the Kislaya Guba plants. Transportation of the “modules“ or “units“ was an approach previously taken when constructing breakwaters, lighthouses, locks and underwater tunnels. But there were “novelties“ involved: its application to a hydraulic plant and the design of a “floating“ platform.

Though at the international congress of Tokyo in 2006, Russian colleagues distraught by the passing of Kislaya’s “father” Bernshtein (1957) were lamenting the surpluses of petroleum that smothered all interest in tidal power in Russia, a different wind seems to blow in the Russian Arctic and plans for tidal power stations are a serious topic since a few years. Feasibility studies have been conducted to develop much larger sites in the north and east of Russia, including Mezen Bay (White Sea) with a potential power capacity of 15 GW and Tugur Bay with a potential power capacity of 6.8 GW.

Usachev *et al.* (2004) reviewed large-scale use and observations made over 35 years of operation at the Kislaya Bay TPP. The TPP has operated successfully, with moving parts underwater, under extreme climatic conditions. The plant has been used as a biological test site in a nearly closed-off basin that included fisheries - and mariculture - observations. A variety of units were tested among which sorption and electrolytic and tests for cathodic behaviour. The report confirmed that a TPP can be integrated into a power system, in basic and peak periods of the load diagram, allowing for the specific conditions of tidal energy generation.

Russia has a 17 million kW capacity and could transfer to the combined European power system 50 TWh per year and the proposed Tugur station could add a capacity of 8 million TWh/year utilizable by the coastal regions of the Russian Federation and Japan. He pointed out that if the American proposal of constructing a combination transport and power tunnel under the Behring Strait would ever materialize, a Penzinskaya TPP could be part of the complex, with a capacity of 87 million.

THE NORWEGIAN ARCTIC PLANT

Hammerfest, in Norway, is the most northerly city (Fig. 4) This “Arctic” city has been one of the leading sites on the foreground of tidal power utilization experiments in the 21^{st} century. Indeed, while the British Marine Current Turbines company has conducted several tests in Great Britain which hold great promise for the development of tidal power tapping. One test concluded in February 2010 opens up new vistas in commercial deployment.

Evopod, close in concept to traditional windmills operating under the sea, is a semi-submerged floating approach tested in Strangford Lough., the same area where SeaGen completed in 2010 successful tests. A prototype is tested at 1/10th scale. The advanced hull form maintains optimum heading into the tidal stream and is designed to operate in the peak flow of the water column. SeaGen, made up of two axial flow rotors, each of which drives a generator, is currently the only commercial scale device installed anywhere in the world. The turbines are capable of generating electricity on both the ebb and flood tides because the rotor blades can pitch through 180˚.

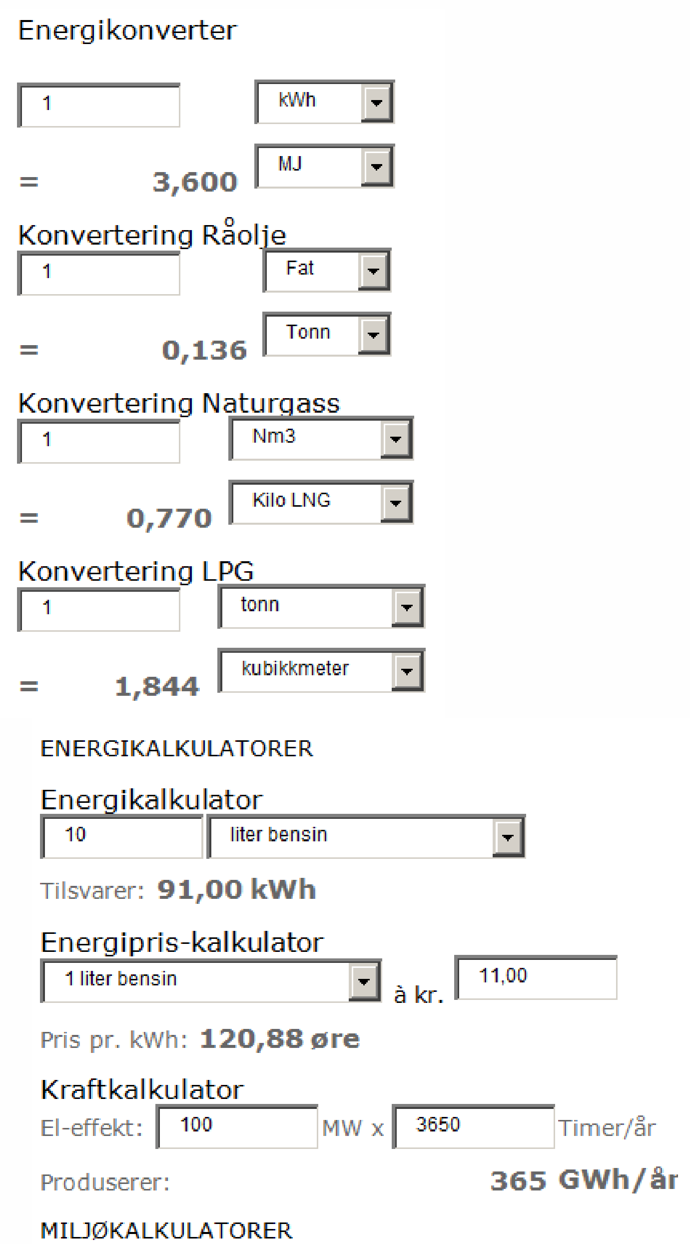
Fig. 3. Wave energy harnessing at Toftestallen, Norway

Prototypes currently operating include a prototype connected to the grid in 2003, near Hammerfest, in Northern Norway, actually at Kvalsund. The turbine has a reported capacity of 300 kW. The Norwegian company Hammerfest Strøm went one better to MCT and connected their 300 kV tidal generator machine to the town of Hammerfest's grid, thus becoming one of the first grid connected tidal turbine schemes in the world. The Norwegian company believed that it would have its first tidal farm of over 20 second generation devices operational before the end of 2008. This would have been the 3rd phase of these "Blue Concept" project and would result in a tidal farm that would produce 10 MW of renewable electricity.

Fig. 4. Harbour of Hammerfest, site of trial tidal power scheme

Hammerfest-Strøm-UK received a £ 3.9m grant from the British Carbon Trust for the construction and testing of the HS10001MW tidal power device at the European Marine Energy Centre (EMEC) in Orkney, Scotland. Design and pre-engineering are completed. The company works with Scottish Power Renewables that is planning to install the device as part of a 10MW tidal power array in the Sound of Islay by 2012.

The HS1000 is designed based on the 300 kW prototype installed in Kvalsundet. Removed after six years of service, it was re-installed in 2010 and continues to produce electricity for the Norwegian grid.



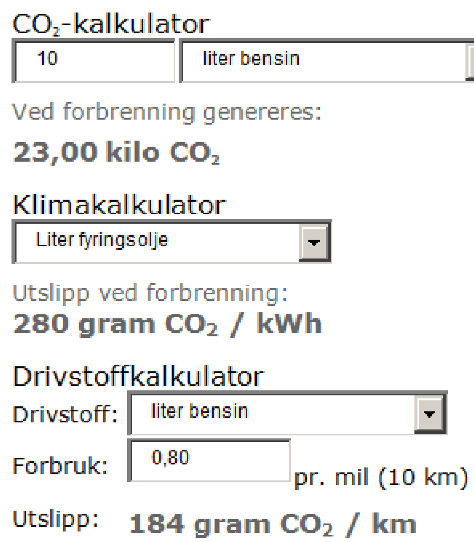


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Fig. 6. Wave energy central of Toftestallen. Energy calculations, showing oil (gas, petroleum) equivalents and CO² releases avoided (for © see above)

MARINE WINDS

Though the energy from marine winds is regionally considerable no large harnessing scheme of offshore winds appears to have been located in or near Arctic areas. Large assemblages of wind turbines, common in Northern Europe, are located at much lower latitudes (Fig. 6). Nevertheless, some individual turbines show up in the landscape. There are, for instance, a few turbines capturing marine aeolean energy on the shore of Toftestallen, the city where a wave harnessing scheme was installed by Kværner (Fig. 7).

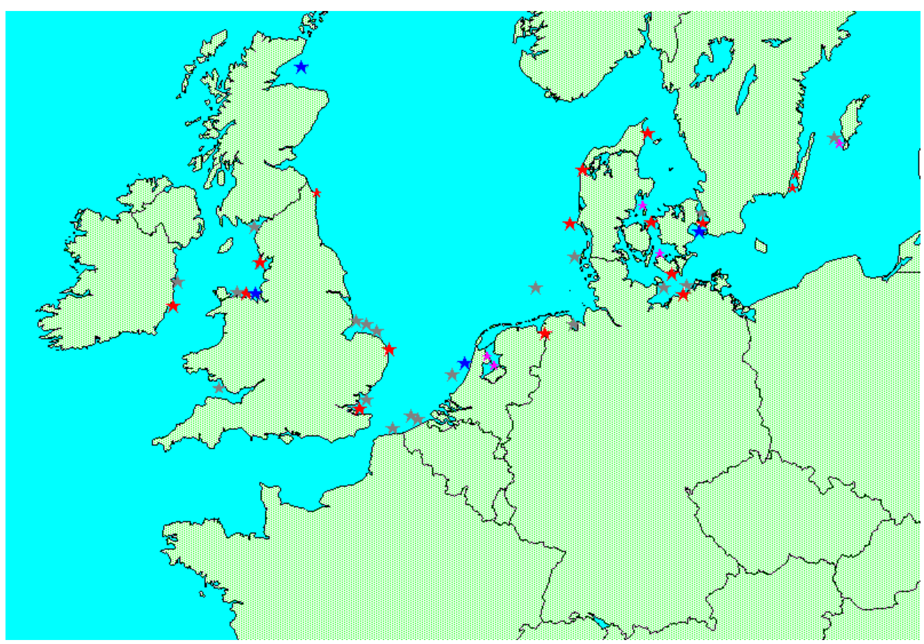

Fig. 6. Main wind energy installations in Europe, both in use and planned: *(2006)

Fig. 7. Toftstallen. Wind turbines at the shore. Wave energy capturing facility (Upper left of photograph) Aerial view [Kværner Inc.]

AN OTEC INSPIRED IDEA?

Other schemes that belong to the group of ocean energies have been either proposed for or tried out in polar waters. More than a quarter of a century ago an article from a Belgian physicist appeared in the quarterly periodical of the University of Rhode Island Graduate School of Oceanography. In it, the author - G. Steinman, if our memory does not fail us - suggested a “sort of” air/water OTEC that would exploit the polar area temperatures differences between the “warmer” waters and the colder polar air. The idea raised some eyebrows at the time, but to our knowledge, there has been no follow-up.

During winter on Arctic coasts, the difference of temperature between seawater and that of local air can reach 40°C, with water warmer than air. A closed-cycle OTEC system could exploit this difference. Long pipes to extract deep seawater would not be necessary making a system based on this concept less expensive than OTEC. Transmission might be expensive, but needed, as a market would not be close by.

THE WAVES AND STORMS TO HAVE THE LAST HURRAH?

More practical perhaps have been attempts to utilize wave energy. This journal published some years ago an extensive study of the waves as a source of energy, over the signatures of Falcao and his colleagues and authored recently another review (Falcao, 2010). For close to a decade Portuguese have held conferences on wave power in the Azores with an eye on implanting a wave energy central on these islands; they also decided to deploy a version of the Pelamis™ device off the coast of their motherland. Wave power schemes have been proposed - and some tried out - for over a century. Again in Norway, an operating plant was at work and functioned quite properly “using Arctic waters”.

In Norway, the sea-lens concept was introduced; indeed, in Toftestallen, the world’s largest oscillating water column system with a capacity of between 500 and 1000 kW functioned properly during six years but was unfortunately wrecked in 1998 during a particularly heavy storm. Not reconstructed thus far (2010), it is listed as “decommissioned”.

Two pilot power plants were contracted and tested, one of them the 500 kW multi resonant Oscillating Water Column (OWC) installed at Toftestallen in November 1985. A unit of the TAPCHAN (TAPered CHANnel) wave power device was simultaneously inaugurated. The 19.6 m steel tower stood on the seabed in 7 m of water. The wave inlet spanned 1 m above and 1 m below the water level. The design used a modification of a Wells turbine and was capable of operating at 1,500 rpm. Damages sustained by the device might have been less severe had the tower been in concrete and the turbine and generator housed further inland.

Will storms that have a record of destroying wave harnessing schemes for decades have the last hurrah and discourage efforts of tapping that ocean energy source?

WRAP-UP

The Rance River plant has been a success, even if many of its - for the times - revolutionary features are no longer on the forefront of technology and construction. Cofferdams have yielded to module construction, resulting in considerable capital investment costs. Bulb turbines can be replaced by Straflo (straight flow) ones. Low head turbines multiply the number of suitable sites. Bi-directional generation does not appear to be a bonanza, even though some tidal stream turbines boost this characteristic. Pumping operations may be dispensed with as its net production is put in doubt. The Rance River Plant has had a few “off-springs“, but not as many as one may have expected or at least hoped for. Inexpensive hydrocarbons are on the forefront of the reasons for the tidal power development slumber. Only the spectre of shortages, and concern for global warming and climate changes - with dire consequences - seem to spur on development of ocean energies.

Economics, supply, environmental and ecological outfalls are as many reasons to turn to the sea for additional sources of energy. Some voices predict that oil and gas supplies are being rapidly depleted and that by mid-21st century we may well run out of gas and oil. Many climate changes, *n‘en déplaise à certains politiciens*, are anthropogenic; reefs and glaciers are disappearing, CO^2 oblige. The problem is no longer a matter for just scientists to worry about, it has huge social outfalls. Extreme climatic conditions - and famine - are the cause of the death, annually, of 160,000 people (Rourke *et al.,* 2010).

REFERENCES

Bernshtein, L.B. and Usachev, I.N., 1957, Utilization of tidal power in Russia in overcoming the global and ecological crisis: *La Houille Blanche-Rev. Int. de l’Eau* **52,** 3, 96-102.

Chaineux, M-C. P. and Charlier, R.H., 2008, Women’s tidal power plant: Kislaya Guba’s 40 candles: *Renew. Sustain. Ener. Rev.* 12, 8, 2508-2517

Charlier,R.H., and Justus, J.R., 1993, “Ocean Energies-Environmental, and Economic and Technical Aspects of Alternative Power Sources,” Amsterdam, Elsevier *Elsevier Oceanography Series N°57,* 534p.

Falcao, A.F. de O., 2010, Wave energy utilization: a review of the technologies: *Renew. Sustain. Energy Rev.* 14, 899-918.

Fry, C., 2005, All at sea (tidal power): *Power Eng.* 19, 5, 24-27.

O'Rourke, F. Boyle, F. and Reynolds, A., 2010, Tidal Energy Update 2009: *Applied Energy* 87, 398-409.

Usachev, I.N., *et al.,* 2004, Performance control of a marine power plant in the Russian Arctic coast and prospects for the wide-scale use of tidal energy: *Power Technol. & Engng.* 37, 4, 201-206.