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OSCILLATING WATER COLUMN PLANT

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ABSTRACT

This article is describing the way of construction and operation of an oscillating water column system in order to recover as much as possible from the waves energy. The oscillating water column plant is used for the production of electrical energy by tidal currents, and it is currently the most widespread and economical method for the conversion of wave motion. The environmental impact of these infrastructures remains very low: no emissions of gas or any waste during their operation. In addition, the swell is a formidable source of energy.

Keywords: wave energy, oscillating water column, turbines

1. INTRODUCTION

The attraction of electricity from marine sources is not new.

In fact, there was already a tidal power plant in Brittany (at Rance near Saint-Malo) in 1966 which, thanks to turbines, produces electricity.

Nowadays, researchers tend to create small production units that can be installed a few kilometers from the coast.

Following the current problems concerning the environment and the successive increases in the cost of fossil fuels, projects allowing the exploitation of wave energy are in full development. And thanks to new technologies, the machines developed are more and more efficient and resistant.

Several techniques have been explored to extract energy from the sea and its movements:

- recover the strength of the tides as had been the case in the Rance tidal power plant
- recover energy from underwater currents using tidal turbines (the equivalent of wind turbines for water instead of air)
- exploit the temperature differences between surface water and deep water by heat pumps
- recover the energy of the waves thanks to wave-power machines which have taken a certain lead over other possibilities of energy recovery.

2. WAVE ENERGY

The swell is a set of waves triggered over tens or even hundreds of kilometers. It is defined by its direction (East, West, ...) and its height (in meters).

It forms in the middle of the ocean or the sea as a result of a conflict of air masses. This then leads to the formation of a depression with most often the creation of gusts of wind on the surface of the water. The swell is then formed.

The size of the swell depends on the depth of the water: the deeper there is, the bigger the swell can be.

The swell moves on average at a speed of 30 km /h.

Wave energy refers to mechanical energy composed of kinetic energy (speed of water particles) and potential energy related to the displacement of the sea surface under the action of the swell (or deformation of the surface some water).

Tab.1. *Swell measurement using the Douglas scale*

Scale	Swell	Sea state
0	None	calm
1	>10cm	wrinkled
2	10cm< x <50 cm	beautiful
3	50cm< x <1,25m	not very rough
4	1,25m< x <2,5m	turbulent
5	2,5m< x <4m	rough
6	4m< x <6m	very rough
7	6m< x <9m	heavy
8	9m< x <14m	very heavy
9	>14m	huge

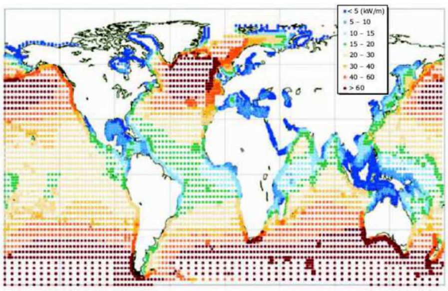

Fig.1. Global distribution of the average wave energy resource

A part of this energy can be recovered thanks to various devices: floats and oscillating rafts, compression or vacuum bells, etc.

We can measure the energy of the swell E:

$$E = (1/8)\rho g H^2$$

With:

p - density of water.

g - gravity field intensity.

H - wave height.

3. OSCILLATING WATER COLUMN PLANT

One of the first uses of wave energy was that of power generation units using the so-called "oscillating water column" method. These are small power plants built on the coasts of countries where the coastal swell is quite important. We will present now this type of installation in more detail.

3.1. PRINCIPLE OF OPERATION

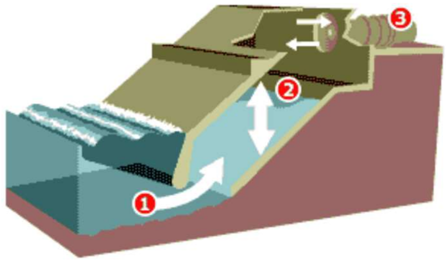

Fig.2. Sectional view of an oscillating water column power plant

The principle in itself is relatively simple: the swell (see 1 fig. 2) increases the height of water in a concrete column fixed to the shore (see 2 fig. 2). This sudden rise in water will reduce the volume of the cavity and therefore compress the air inside. This air will have no other choice than to be evacuated under pressure at the top of the column through a turbine coupled to a generator (see 3 fig. 2).

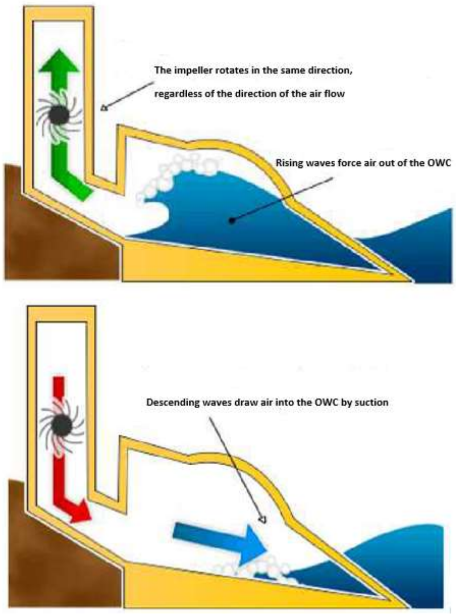

Fig.3. Schematic diagram of the coming and going of the swell in the column

The turbine will be rotated by the flow of compressed air. Once the maximum amplitude of the wave has been reached, it descends and causes a call for air in the column. This time, the air forcefully enters the column in the other direction and spins the turbine again. It produces electricity. It should be noted that whatever the direction of the air flow (inlet or outlet of the column), the turbine will always turn in the same direction, guaranteeing constant production of electricity. (see fig. 3).

3.2. POWER AND LOCATION

We have previously seen the need for the swell to compress the volume of air in the column. You should know that the swell is characterized by the height of the swell H (maximum difference in level between a successive peak and a trough) as well as the period determined by the wavelength L of the swell. (see fig. 4) These two terms will make it possible to calculate the theoretical power contained in the swell (in kW/m).

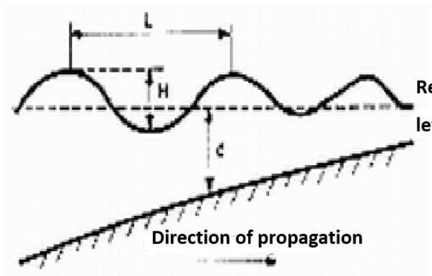

Fig.4. Schematic representation of the swell

Theoretical calculation:

The wave of the swell can be thought of as a sine wave. We will therefore represent its period:

$$T = \sqrt{\frac{2\pi\lambda}{g}}$$

with "λ" the wavelength of the swell and "g" the force of gravity

The power contained in the swell is a function of the amplitude of its waves. It is determined according to this expression:

$$P = \frac{\rho g^2 a^2 T}{8\pi} \quad \text{(in kW/m)}$$

with "a" the amplitude of the wave, equal to H/2.

It is therefore observed that the amplitude of the swell as well as its wavelength are preponderant in determining the potentially recoverable energy. However, these factors depend on the quality of the seabed, the strength of the wind at sea, as well as the space necessary for the development of a swell with strong periods. Each coast will therefore have a different and more or less exploitable energy potential. Also, some coasts, such as those of Ireland, are more favorable to the operation of an oscillating column factory (see fig. 5) because of a very high wave amplitude.

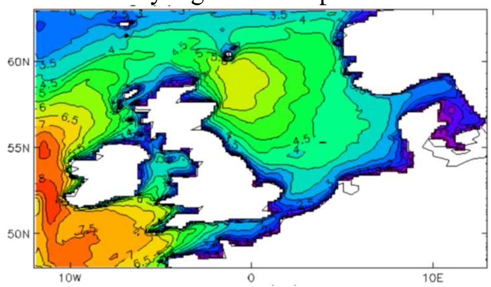

Fig.5. Swell amplitude planisphere

3.3. A CONCRETE EXAMPLE - THE LIMPET500

The LIMPET500, or "Land Installed Marine Powered Energy Transformer", is a 0.5 MW power plant built on the Isle of Islay in Scotland, using the principle of the oscillating water column where a first 75kW unit was built in order to develop and test this technology. (see fig. 6).

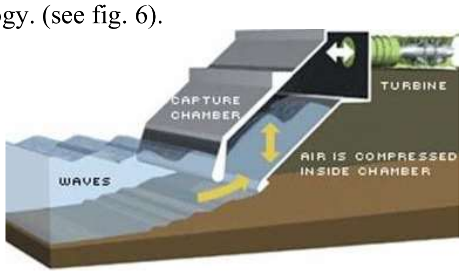

Fig.6. Schematic view of the Limpet 500

This is the first commercial use of a production unit of this type. The electricity produced is in fact injected into the national grid.

The energy produced corresponds to the demand of the island. It is therefore a good example of electricity production for local consumption.

4. ADVANTAGES AND DISADVANTAGES

Disadvantages

The major drawback for the development of this method of electricity production is the financial investment of the companies. Indeed, as we have previously seen , to date, only a production unit of the "oscillating water column" type is operational. The lack of knowledge and feedback is not in favor of this method, unlike other renewable energy sources such as wind or the sun through wind turbines or photovoltaic panels, already proven.

Socially, this type of power plant may not be well received, especially if they are built close to homes. Indeed, the noise of the turbine is strident and very annoying. They can also harm fishing and local wildlife because of the large land and coastline that are necessary for its operation.

Finally, a strong and regular swell is needed for proper operation, which reduces the coasts potentially suitable for receiving this type of power plant which, moreover, are not conducive to high electricity production.

Advantages

The main advantage is obviously to produce electricity from a resource almost unused and free: the swell. The swell is an infinite reservoir of energy which makes it possible to define it as renewable energy.

Despite the need for a steady and strong swell, the so-called "oscillating water column" technology can be used virtually on all coasts of the world.

The reduced amount of electricity produced is an advantage if this type of plant is used for the production of electricity in islands or regions with low demand. This can be a very interesting alternative to small coal or oil power plants.

Finally, in order to limit damage on the coasts and above all to increase yields, this technology can be transposed to off-shore, where the swell is stronger (see fig. 7).

Fig.7. Off-Shore oscillating water column unit

5. CONCLUDING REMARKS

Wave energy is a great resource, especially offshore. Near the coast, the wave height is lower, but the water depth is less and the connection to the land is more economical.

The ability to survive storms is a critical design factor. All equipment must resist fatigue to the stresses of the marine environment.

Wave energy, through oscillating water column power generation units, will play an important role in a long-term goal of greater use of renewable energy.

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