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HYDROPOWER PLANT

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Abstract: Ocean waves are an immense, unused source of energy. Since global attention is nowadays constantly being drawn to the fact that the level of CO_2 is rising, creating the so called "greenhouse effect", and influencing further climate changes, the focus on generating electricity from renewable sources forces itself as an important area of future research. The possibility to exploit the energy potential created by sea waves indisputably exists. Various researches conducted in the field of unused energy sources prove the necessity of seriously considering this potential of sea waves. The illustration of this point in noted in a recently performed estimation that up to 15 per cent of current UK electricity demand could be met by wave energy, and when this is combined with tidal stream generation, even up to 20 per cent of the UK demand for electrical power could be met. This paper introduces the readers to the topic of water power, as a natural source of renewable energy, investigating the possibility of using power of waves as one of the technically and ecologically appropriate solutions of exploiting this renewable natural source. It is a fact widely acknowledged that climate change and global warming are the number-one challenge of the contemporary world; practically every available research predicts that with the current rate of development the world is heading for at least 2, and even more likely 3-4, degrees warmer climate by the end of this century. As energy production and use account for two-thirds of global greenhouse-gas emissions, the energy industry is in a key role to cut emissions – while powering economic growth, boosting energy security and increasing energy access. In view of this, hydropower can make a major contribution to climate change mitigation. Not only is hydropower practically CO_2-free, thus eliminating its possible contribution to the greenhouse effect, but it is also both more efficient and flexible compared with existing fossil alternatives for base load and balancing power. Even though the world is aware of the potential of hydropower, and despite the fact that many wave energy devices are nowadays being investigated, most of these are currently at the research and development stage, with only a small range of devices having been tested at large scale, deployed in the oceans. Thus, one of the goals of this paper would be to present the technology used to turn the power of waves unto electric power, as well as the various types of turbines and devices which represent the latest technological achievements in this area. The goal of this paper is also to present the existing devices, their manner of functioning, and their efficiency and safety from the environmental aspect. It is also important to note that hydropower's own overall environmental impact is limited, thus making hydropower more benevolent to the environment than other energy sources that have been exploited so far.
Keywords: Sea waves, Turbines, Renewable energy sources, High and low tide.

1. INTRODUCTION

For millions of years the Earth has managed to create all that it needs for the life on it to further develop. The process of evolution brought to the surface of the Earth creatures which, rather than merely surviving, strive for further development, seek beauty of life and aim at improving technology to support these tendencies. However, the development of technology has also led to the destruction of nature, and people, after many years, finally show understanding of the problem they have created and willingness to work on the solution of this problem. Global warming, one of the major problems nowadays, is actually detected in an increase in the average temperature of air and ocean water, this problem becoming particularly evident from the mid-20th century onwards. From the beginning of the 20th century by the end of it, the temperature of the Earth's surface increased for 0.74±0, 18 C°. This increase in temperature is caused by an increased level of gases, "the greenhouse effect", these resulting from various human activities, such as burning of fossil fuel and destroying of forests.

For the past hundred years, the amount of carbon dioxide in the atmosphere increased for 25%. As this gas lets through the short-length waves of the Sun, and absorbs the long-waves radiation of the Earth, this leads to an increase in the temperature of the lower layers of the atmosphere, thus producing the so-called "greenhouse effect ". Lately, carbon dioxide is not the sole cause of this effect, but is rather accompanied by various other gases which are emitted into the atmosphere [3] (the examples of such gases being chlorofluorocarbons of Freon, methane, nitrous oxide, ozone). As already noted, "the greenhouse effect" leads to a significant increase in the average temperature on the Earth. This further leads to an increased evaporation and an increased amount of rainfall and a probable change in the schedule of rainfall, all of these having a farther impact on agriculture. In addition, due to spreading of ocean and melting of ice, the level of the world's seas could rapidly increase (maybe even up to 100cm).

The effect created by these gases, both in the present and in the future, would differ from region to region. What is certain is that, even if the emission of the negative gases stops, the temperatures would still be increasing even after the year of 2100.

We are forced to ponder on the issues of ecology and our legacy for the future generation. The whole world is debating on climate changes and prospective measures to be taken in this regard. Some of the options available could be reducing emission of gases into the atmosphere, adopting measures to prevent further damages caused by warming, etc. But most importantly, all these actions are to be accompanied by geo-engineering, which would both take advantages of nature and treat nature in an ecologically appropriate manner at the same time. This is the reason that the renewable energy sources are being used more and more. These renewable energy sources are solar energy, the energy of wind, water, high and low tide, the energy of waves, geo-thermal energy, oxygen energy, as well as biomass.

2. THE POWER OF WAVES AS ENERGY SOURCES

The energy collected from water, i. e. its immense power, represents a source of pure and renewable energy. 71% of the earth surface consists of water. The World Energy Council (WEC) estimates that the electrical energy obtained from all the oceans would be twice the amount of the total amount of the currently produced electricity in the world.

The increased energy demand, as well as striving to reduce the emission of harmful gases into the atmosphere, encourages introducing new ways to obtain energy. The world's scientific circles direct towards renewable energy resources. The amount of energy obtained from oceans, through using the energy of waves, as well as the energy of high and low tide, is more than sufficient and can be obtained in a manner which is ecologically acceptable and economically viable [8].

2.1. Pelamis - Weave Power

Pelamis Wave Energy is a manufacturer of a unique system for generating electrical energy for renewable sources, ocean waves. Pelamis Wave Energy Converter is a result of long year's development of engineering of PWP. This was the world's first commercial machine for generating electrical energy into the network from offshore wave energy, and the first one to be used commercially. Pelamis Wave Energy Convertor (Fig. 1a) is half-submerged structure consisting of joints and cylindrical parts mutually connected. Wave causes movement of these joins, and the resistance to this movement is created by hydraulic frames through which liquid floats under high pressure. This movement pushes the liquid not hydraulic engines which use this mechanic energy to work generators producing electrical power.

The energy collected is via a cable connecting the convertor with the shore is transmitted to the network. Several devices can be connected together and to the shore over a single cable which is laid at the sea bottom (Fig. 1b). The machines currently produced are 180m long, 4m in diameter and with 4 Power Conversion Modules per single machine. Each machine is marked at 750kW. The energy produced by Pelamis depends on choice of location. Depending on height of waves, the machines would produce per average 25-40% of the maximum capacity. For generating electrical power the waves of at least 1m in height are required, and for achieving the nominal strength the waves of 5-6m in height. Each machine can provide sufficient energy to satisfy the demand per electrical energy of approximately 500 households [4].



a) b)

Figure 1. Pelamis machines

2.2. Oyster - Wave Power

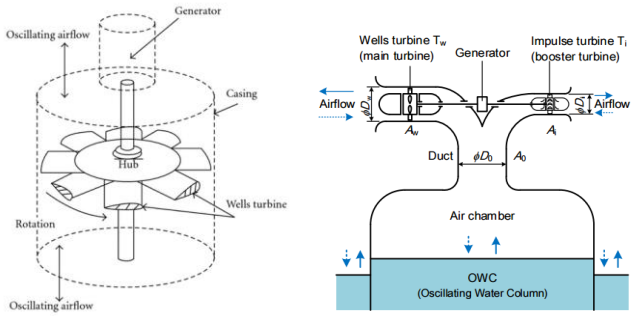
Oyster Wave Energy Converter is a hydro-electric device developed by the energy company Aquamarine Power. The device for "capturing" the energy of waves is situated at the vicinity of the shore and it turns this energy into electrical one. The system consists of a mechanical "wing" tied by joint and connected to sea bottom up to

approximately 10m of depth. Each wave moves buoyant flap, which sets in motion the piston under high pressure of water over pipelines on the shore, a turbine generates electricity. In November 2009, the first complete converter started producing energy when launched at European Nautica Energy Centre (EMEC) [2], [9].

2.3. Technological characteristics of OWC

The technology of using wave power to move turbines for obtaining electrical energy is quite "young" compared to wind generators or the turbines set to "collect" the power of water currants. The whole process is based on the Oscillating Water Column – OWC. The turbine moved by the air, pushed by water that enters through the opening at the lower part of the station submerged into water, is always rotated in the same direction, no matter the direction of air movement [1]. This manner of operating is possible since the blades of turbine are not fixed and can adjust in position to the air movement. In this manner, the maximum exploitation of each wave, i.e. each oscillation is achieved. The technology of Oscillating Water Column is connected with Wells Turbine and a highly functional system is obtained [1], [6].

The Wells turbine is a low-pressure air turbine that rotates continuously in one direction independent of the direction of the air flow (Fig. 2a). Unlike the conventional turbines, it is of symmetrical aero-dynamic airfoil, which implies that the angle at which air hits the blade is much higher. Its efficiency is lower than that of a turbine with constant air stream direction and asymmetric airfoil. One reason for the lower efficiency is that symmetric airfoils have a higher drag coefficient than asymmetric ones, even under optimal conditions. Also, in the Wells turbine, the symmetric airfoil runs partly under high angle of attack (i.e., low blade speed / air speed ratio), which occurs during the air velocity maxima of the oscillating flow. The efficiency of the Wells turbine in oscillating flow reaches values between 0.4 and 0.7 (Fig. 2b). By using this bidirectional turbine the necessity to correct the air flow with delicate and expensive air vent systems is avoided. This simple and yet high-quality device was developed by professor Alan Arthur Wells of Queen's University Belfast in the late 1970s [6].



a) graphic representation b) schematic representation

Figure 2. Wells turbine

OWC system with the Wells turbines can be applied in different locations and different operating systems:

- By the shore
- As breakwater (installation is performed at the already existing breakwaters or the new ones are constructed with the Wells turbine)
- In the vicinity of the shore
- At the open sea

According to research on renewable energy, in ocean waves there is sufficient energy to allow the production of 3 billion watts of electric energy [5].

3. THE ENERGY OF SEA WAVES

Waves are created by effects of wind, and wind by effect of the Sun. The basic characteristics of waves are height and length. Time interval between the two amplitudes is proportionate to the second square root of the wave length. The wave energy is proportionate to the square of the wave height and inversely proportionate to the time interval between two amplitudes. The energy abruptly decrease with the depth, so at the depth of 20m it is approximately 20% of the energy, and at the depth of 50m approximately 25 of the energy. The strength of wave can be up to 10kW/m2. For example, for the area of North Atlantic, at the open sea between Scotland and Ireland50% of the time

the energy of waves is 3.9kW/m2 of higher. The strength of waves can be calculated per meter longitudinal at the sea surface [8].

Thus defined strength of waves changes with the speed of wind and depends on season and weather conditions. At the referred part of Atlantic 50% of the time during summer the strength is 10kW/m or higher, and in winter 95kW/m or higher. The length of the shore on all the five continents (without the Poles) is approximately 100 million meters, so if the calculation is made with an average strength of 10kW/m, the average annual strength of 1TW is obtained, i. e. the average energy of approximately 9000TWh, which is around 60% of nowadays produced electrical energy.

In deep water, where the depth of water is higher than half of the wavelength of the wave, the energy is calculated by using the following formula:

$$P = \frac{\rho g^2}{64\pi} H^2 T \approx \left(0{,}5 \frac{kW}{m^3 s}\right) H^2 T$$

where:

P – *the wave energy flux per unit of wave-crest length [W/m],* – *the water density* ρ=1025 kg/m^3, g – *the acceleration by gravity* g=9,81 m/s^2, π –*mathematical constant* π=3.1415926..., H – *height of waves [m],* T – *time period of waves [s].*

For example, in dep water, the waves with the length of 3m and period of 8s would have the energy:

$$P \approx 0{,}5 \frac{kW}{m^3 s} (3 \cdot m)^2 (8 \cdot s) \approx 36 \frac{kW}{m}$$

While during strong storms, the waves of the height of 15m and with the period of approximately 15s, would have the stregth of approximately 1,7 MW/m. The picture 4.3.1 respresents a map of the Earth with the average energy of waves.

It is certain that, due to more easy transmittion of the energy to users on the shore, iy would be more simple to expolit the energy at the proximity of the shore, even though the energy of waves at the open sea is much higher [2]. Usage of the energy of waves would be limited by factors of geography and economy, primarily caused by issues to transmit energy thus produced [7].

4. THE ENERGY OF HIGH AND LOW TIDE

Tide moves an immense amount of water twice per day, and if used, could give a lot of energy – taking the example of the Great Britain, that would be the approximate usage of energy of the country. Even though the electricity power supply is reliable and plentiful process, turning the energy into usable electricity is not an easy. Only about 20 locations in the world have been identified as possible tide-power plants (Fig. 3).

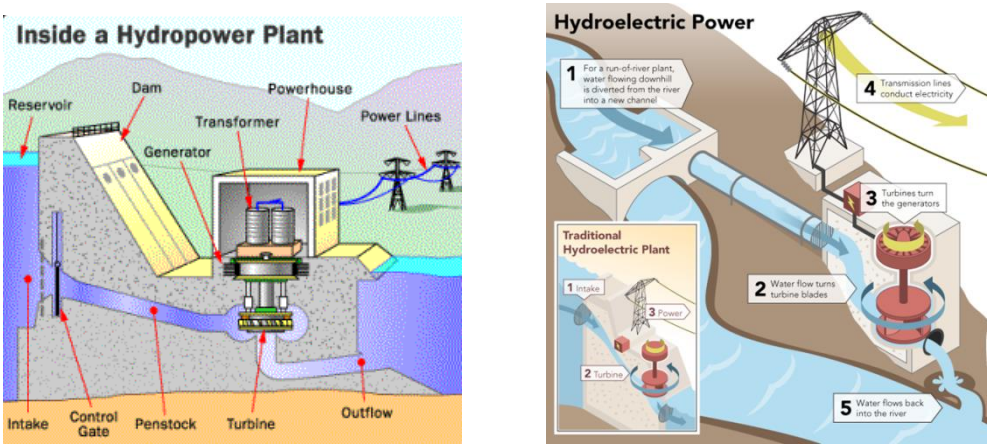


Figure 3. Collecting the energy of high and low tide, graphic representation

5. CONCLUSION

The capacity of deep water waves, ranging from 1 to 10 TW, is indisputably immense, but being such, this capacity could not practically be used all at once. It is estimated that it would be best not to use more than 2 TW of these resources. The locations with the highest potential for using the waves' energy is the West coast of Europe, the North coast of the Great Britain and the coasts of North and South America, as well as the coasts Australia and New Zealand. Taking into account that waves are highly predictable, the occurrence of waves caused by winds can be predicted five days in advance, while the currents, resulting from the high and low tide influenced by the Moon, can be known 100 years in advance.

The power of waves is an inexhaustible, as well as a pollution-free, way to obtain renewable energy. Currently, the full capacity of this natural power is still not entirely used, but the modern world started heading in the right direction, as far as this kind of renewable energy is concerned. Taking into consideration that the immense potential of waves and the energy thus produced has still not been put into full service, there are indisputably plenty of opportunities for progress in this field.

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