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*Full Length Research Paper*

# Ocean wave energy – An option for Nigerian power situation

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**As energy presents itself in various forms, here we will be looking at it from the perspective of wave energy. This paper investigates wave theory and use of some forms of mechanical wave fronts to generate electrical energy. A major means of production of these waves is discussed - being the wave front from the ocean, which is presently a source of worry to the people of Lagos State, Nigeria. These wave fronts from the Atlantic Ocean was analysed and the possibility of converting this unwanted excess energy of the ocean to useful work was considered. Thus, this paper presents a means of harnessing this abundant source of energy considering the waves generated in our coastal belt. The adoption of this form of energy resource would help in the conservation of our fossil fuels, nil-carbon emission and also promote the efficient use of energy.**

**Key words:** Wave power, water column, kilowatt, oscillating water column.

## INTRODUCTION

The world has for generations been enjoying the benefits of energy source, namely fossil fuels. Today, Nigeria practically depends on these fuels consisting of petroleum crude oil, natural gas and coal. Nigeria is presently the 6th highest crude oil producing country and the 7th largest gas reserve worldwide, with about 3 mmb/day and with production capacity growth steadily at about 3% annually, with natural gas averaging about 5 bcf/day with forecast growth to about 30 MTPA respectively (Mohammad and Jumare, 2007; Awogbemi and Ojo, 2009).

It is now universally accepted that fossil fuels are finite and it is only a matter of time before their reserves become exhausted. The need for supplementary or even alternatives that will be non-depletable energy sources has been recognised. These non-depletable sources are replenishable and are also referred to as renewable energy sources as they are available in cyclic or period basis (Mohammad and Jumare, 2007; Awogbemi and Ojo, 2009; Nwachukwu, 2007).

According to Nwachukwu (2007) and Brian (1966), atmospheric pollution from the burning of fossil fuels, depletion of the Earth's natural resources and the fear of radioactive emissions from nuclear plants make the concept of renewable energy resources of primary concern and an attractive form of alternative energy today. Ocean waves are one of the world's most abundant sources of renewable energy, generated as a result of wind blowing over the ocean surface. Since winds themselves originate due to the uneven heating of the atmosphere by the sun, wave energy may be seen as a by-product of solar energy. Wave power refers to the energy of ocean surface waves and the capture of that energy to do useful work - including electricity generation (Wikipedia, Online Encyclopaedia, www.wikipedia.org). Though often co-mingled, wave power is distinct from the diurnal flux of tidal power and the steady gyre of ocean currents. Wave power generation is not a widely employed technology, and no commercial wave farm has yet been established. Plans to install three 750 kW Pelamis

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devices at the Aguçadora Wave Park in Portugal in 2006 have been delayed and no installation had taken place up till now.

During the next 20 years, experts foresee a need for 1500 GW of additional power supply to meet new demand. This equals 15000 power plants that are 100 MW each and 59 million barrels of oil consumed in each day. The World Bank estimates that the developing countries alone will need to spend $100 billion each year for the next 30 years installing new power plants most of which will be in the equatorial Zone. These are astronomical figures that could mean enormous quantities of fossil fuel and 2.2 billion tons of $CO_2$ release to the atmosphere per year; hence, an urgent need to switch to alternate energy. Among the alternate energy resources, ocean wave energy is considered one of the promising alternate energy resources that has high availability factor (day and night) compare with other resources such as wind energy or solar energy (Mohammad and Jumare, 2007; Department of Naval Architecture and Marine Engineering, 2002).

The concept of harnessing wave energy is not new and there have been many ideas patented in the last two centuries alone. These ideas, very few of which were constructed and tested at sea, and until the 1970s the powering of navigation aids represented the only commercial exploitation of wave power. Early this century, several navigation buoys were equipped with a vertical tail tube open at the bottom to allow the waves to oscillate the column of water within. The resulting piston like motion of the water was used to force air through a whistle and the initial oscillating water column wave power devices were born. In the 1960s the whistle was replaced with a turbine generator (Awogbemi and Ojo, 2009; Brian, 1966).

## Economic considerations

It is interesting to examine the criteria used when renewable energies are considered from an economic perspective in comparison to criteria used for other sources of energy. In the case of fossil fuels, it is accurate to calculate the sale price of 1 kWh of electricity and deduce from this that if the price is lower than for wave energy, then it is the cheaper option. How could it be without taking into account the hidden costs associated with fossil fuels such as the amount of money now devoted to researching the extent and possible ways of alleviating the damage caused to the environment? Neglected also are the research costs spent on developing the fossil fuels to their present levels of efficiency which far exceed those of renewable energies (Nwachukwu, 2007; Brian, 1966).

It has been estimated that if less than 0.1% of the renewable energy available within the oceans could be converted into electricity, it would satisfy the present world demand for energy more than five times over. The problem is that it is not easy to harness this energy and convert it into electricity in large amounts. Thus, ocean wave power stations are rare (Department of Naval Architecture and Marine Engineering, 2002; www.wavegen.co.uk (2006).

## Environmental implications

Ocean waves are a source of clean, natural and renewable energy. The harnessing of wave power does not cause large carbon dioxide emissions, which would allow it to play an important role in counteracting the threats of global warming. There are no dangerous and harmful by-products which are comparable to the radioactive waste produced at nuclear power plants. As with any interactions between humans and the rest of the natural world there is however, an impact on the environment some aspect of which being negative though not all (offshore devices, for example, could help reduce coastal erosion as is the case with the Bar Beach at Victoria Island, Lagos). The construction of large offshore devices could have serious consequences for wave patterns and sedimentation rates. In areas in need of coastal protection this may be of benefit. The impact on drift patterns and secondary effects on the local ecology will be the main point in further research and study of these devices (Nwachukwu, 2007; Brian, 1966).

## MATERIALS AND METHODS

### Basic physical concepts

In general, large waves are more powerful (Wikipedia, Online Encyclopaedia, www.wikipedia.org). Specifically, wave power is determined by

- Wave height,
- Wave speed,
- Wavelength, and
- Water density.

Wave size is determined by wind speed and fetch (the distance over which the wind excites the waves) and by the depth and topography of the seafloor (which can focus or disperse the energy of the waves). A given wind speed has a matching practical limit over which time or distance will not produce larger waves. This limit is called a "fully developed sea."

Wave motion is highest at the surface and diminishes exponentially with depth. However, wave energy is also present as pressure waves in deeper water. The potential energy of a set of waves is proportional to wave height squared times wave period (the time between wave crests). Longer period waves have relatively longer wavelengths and move faster. The potential energy is equal to the kinetic energy (that can be expended). Wave power is expressed in kilowatts per meter (at a location such as a shoreline).

Figure 1 depicts when an object moves up and down on a ripple in a pond, it experiences an elliptical trajectory.

The formula below shows how wave power can be calculated.

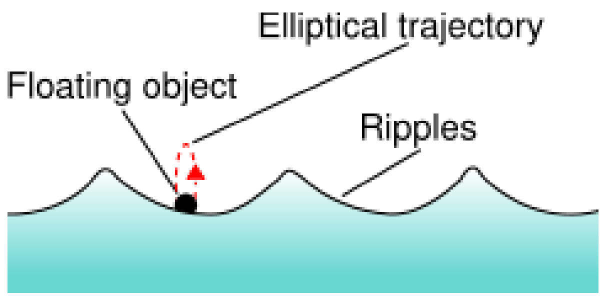


**Figure 1.** When an object moves up and down on a ripple in a pond, it experiences an elliptical trajectory.

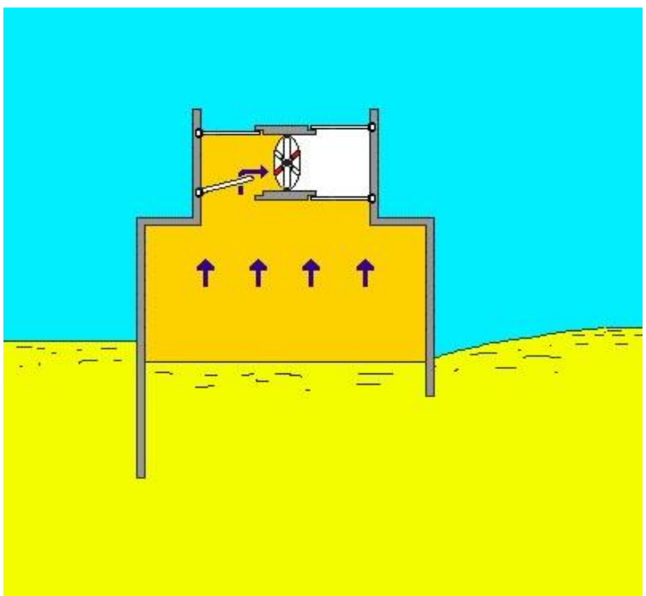

**Figure 2.** Schematic of an oscillating water column (Department of Naval Architecture and Marine Engineering, 2002).

Excluding waves created by major storms, the largest waves are about 15 m high and have a period of about 15 s. According to the formula, such waves carry about 1700 kW of potential power across each meter of wave-front. A good wave power location will have an average flux much less than this: perhaps about 50 kW/m.

Formula: Power (in kW/m) = $k H^2 T \sim 0.5 H^2 T$

where k = constant, H = wave height (crest to trough) in meters, and T = wave period (crest to crest) in seconds (Wikipedia, Online Encyclopaedia, www.wikipedia.org).

**Description of the oscillating water column (OWC) system**

According to the Department of Naval Architecture and Marine Engineering (2002), this system is considered to be the closest to commercial maturity, as the principle of operation is simple and the construction uses conventional technology. The major component of an OWC system is a chamber, which is a fixed structure with its bottom open to the sea (Figure 2). The wave motion inside the

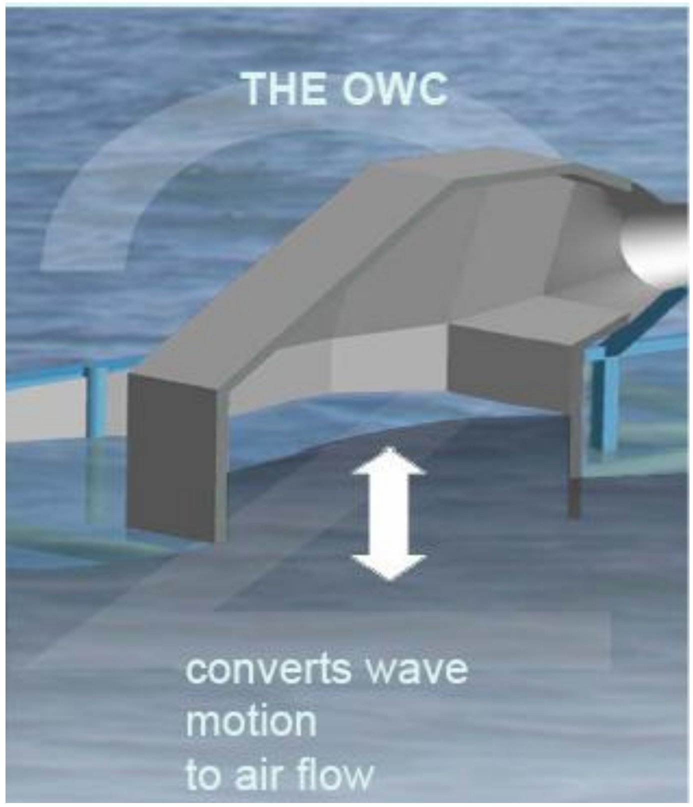


**Figure 3.** How an oscillating water column (OWC) works (Hydrokinetic and Wave Energy Technologies, 2005).

chamber alternately compresses and decompresses the air that exists above the water level inside the chamber.

As a result, an alternating stream of high velocity air is generated. This airflow is driven through a duct to a turbine generator that is used to generate electricity. The turbine generator used is a special turbine which has the unique property of turning in the same direction regardless of which way the air is flowing across the turbine blades. Thus, the turbines continue turning on both the rise and fall of wave levels within the chamber. The turbine drives the generator, which converts this power into electricity. The experimental OWC we used included the chamber and the duct. Figure 3 and 4 explains how an oscillating water column (OWC) works.

Macro model of the chamber was designed and installed on a permanent base which can be moved back and forth along the towing track of the channel at Marine Hydro dynamics Laboratory of the Department of Naval Architecture and Marine Engineering at University of Michigan (Figure 5 and 6). The characteristics of wave maker and water flume are taken as follows: Tank length-109.70 m, tank width- 6.70 m, tank depth- (to edge of trough)- 3.05 m; periods of waves: 0.63 s to 2.2 s; wave heights: up to 0.33 m. Wave maker type: Plunger type capable for generating regular and irregular waves; computer generated for any irregular wave spectrum.

## EXISTING WAVE ENERGY PLANTS IN THE WORLD

England: One set of OWC wave power station, with installed capacity of 70 kW, was built in the west of England under the support of the Department of Energy in 1991. It used a twin-rotor symmetrical wing turbine

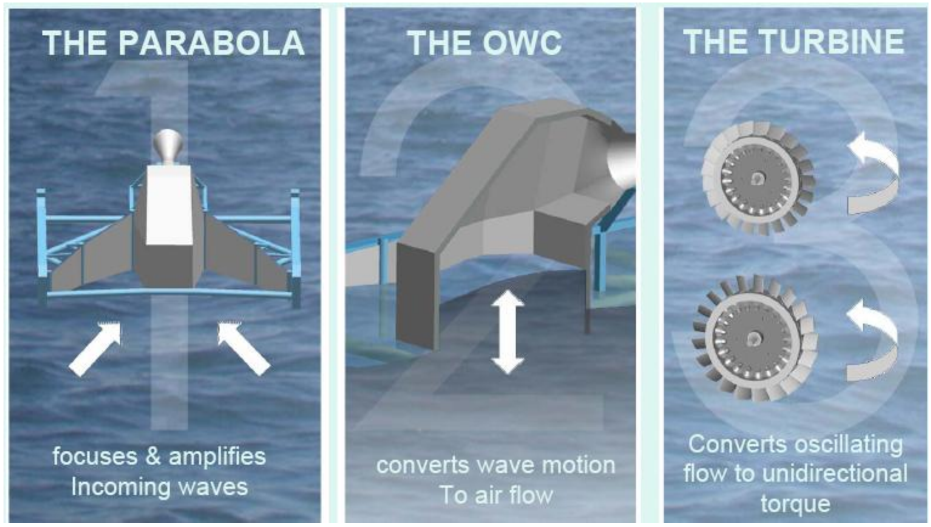


**Figure 4.** Principle of power conversion (Hydrokinetic and Wave Energy Technologies, 2005).

**Figure 5.** Newly design oscillating water column type chamber at the Department of NA&ME, University of Michigan (Department of Naval Architecture and Marine Engineering, 2002).

generator. The average electric power generation was 7.5 kW.

Norway: One set of multi-resonance OWC wave power station, with the installed capacity of 500 kW, was put into operation in an Island near Bergen of Norway in 1985. It used a symmetrical wing turbine generator. In December 1988, the structure failed during a storm.

Japan: One set of OWC wave power station, with the installed capacity of 30 kW, was put into operation on the shore 99 miles away eastern to Tokyo in 1988. It used a conventional impulse turbine generator. The average electric power generation was 6 kW. The power station has been operating in normal conditions for 10 years (Department of Naval Architecture and Marine Engineering, 2002).

## CHALLENGES

The challenges of wave power are:

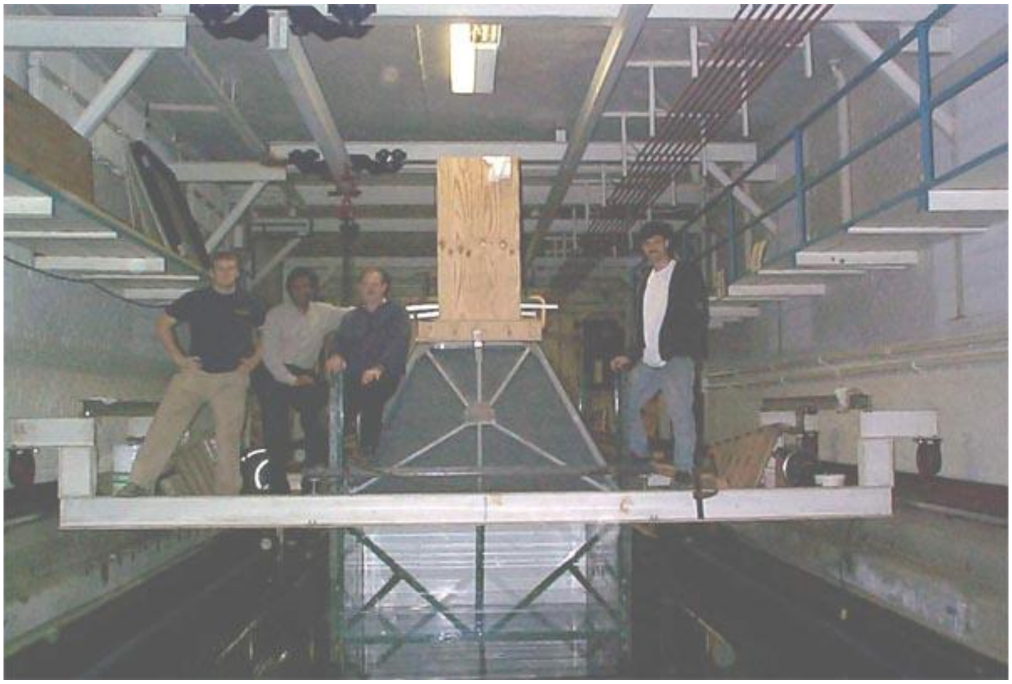

**Figure 6.** Research-site.

i) Efficiently converting wave motion into electricity: Generally speaking, wave power is available in low-speed, high forces and motion is not in a single direction. Most readily-available electric generators are being operated at higher speeds, with lower input forces, and rotate in a single direction.
ii) Constructing devices that can survive storm damage and saltwater corrosion. Likely sources of failure include seized bearings, broken welds, and snapped mooring lines. Knowing this, designers may create prototypes that are so overbuilt that materials costs prohibit affordable production.
iii) Low total cost of electricity: Wave power will only be competitive when total cost of generation (p/kWh) is reduced. The operative effective design will be the one that develops the lowest-cost system (which includes the primary converter, power takeoff system, mooring system, installation and maintenance procedures).

## POSSIBILITIES FOR FUTURE DEVELOPMENT

At its present stage of development wave power is an ideal energy source for *small scale utilisation* such as Island communities, oil rigs on the ocean, etc. This has important implications for Nigeria particularly regarding the saving of fossil fuels currently being used by such communities. Also worth noting is the fact that Lagos and other highly populated part of the country are close enough to the ocean to benefit from this form of energy: thus reducing greatly the cost of using fossil fuel. *Large scale harnessing* of wave energy will be made a reality within the next ten to fifteen years and this will be possible if sufficiently large resources are made available now to a strategically planned programme for Nigeria so as to develop her own wave technology.

On-shore and near-shore OWC devices are at an advanced stage of prototype development with device teams in Japan, Portugal and the UK. Nigeria is lagging behind in these developments, therefore research funds should be directed also in this source of renewable energy programme.

## Conclusion

It has been shown from this paper that the ocean wave energy is a viable source of cheap renewable energy that is capable of solving the electricity problems in Nigeria. Harnessing the energy from the ocean front, which hitherto were wasted energy to us, can be put to effective use, creating more jobs as the power plants are installed. It is therefore recommended that more funds should go into the research of this viable source of renewable energy.

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