4th International Conference on Science, Technology and Management
India International Centre, New Delhi (ICSTM-16)
15th May 2016, www.conferenceworld.in ISBN: 978-81-932074-8-2

ELECTRICITY FROM OCEAN WAVES: A REVIEW OF THE EXISTING FACILITIES

Kumar Kislay[1], Gaurav Goet[2], Lokesh Choudhary[3]

[1,2]*B.Tech. Student,* [3]Assistant Professor, *Dept. of Civil & Environmental Engg,*
TheNorthCap University, Gurgaon (India)

ABSTRACT

The basic input to agricultural, industrial and the national economy is energy. It is also seen as an instrument to improve the quality of life. Oils, Coal, nuclear energy to some extent and hydroelectricity are the primary commercial energy inputs to the Indian economy. With rising fuel costs and environmental concerns, it is the need of the hour to focus on clean, safe and sustainable alternative energy sources for power generation. The present study highlights a review on existing unique and promising concept of harnessing the energy of the oceans, by converting the relentless force of waves into useful mechanical work to generate electricity. The main focus of the paper is to critically analyse the techniques that are deployed in the field for the aforementioned purpose and suggest key points which can be worked out or incorporated in a new system to improve the functionality in this sector. The power available and the efficiency of various techniques has also been compared in this article.

Keywords: ***Conversion techniques, Efficiency, Ocean Wave Energy, Renewable and Non-Renewable Energy resources***

I INTRODUCTION

Wave power is the energy includedin surface of ocean waves and this energy can be captured to obtain mechanical work which is useful. Sea waves can prove to be promising energy transporter in all renewable energy resources, since huge amount of energy resourcesthey are contained in almost all locations geographicallypossible. The global theoretical energy from waves corresponds to 8×10^{6}TWh/year, which is about 100 times the total hydroelectricity generation of the whole planet. To produce this much amount of energy using fossil fuels it would result in an emission of 2 million tons of CO_2. As defended by the Kyoto Protocol, wave energy can help in diminishing the gases deemed as pollutant in the atmosphere [1]. Today the greatest attention in the world is devoted to energy resources because their use is usually irreversible, but the supplies of traditional fossil fuels (oil, natural gas) are running out fast. This is why over the last few decades attention has been given on renewable energy resources and ways to increase energy efficiency.

II NON-RENEWABLE ENERGY SOURCES

A non-renewable resource (finite resource) is a resource that does not renew itself at a sufficient rate for sustainable economic extraction in the meaningful human time-frames.Non-renewable sources take millions of years to be replaced. Therefore, people can rely only on those deposits which already exist. Earth minerals and metal ores, fossil fuels (coal, petroleum and natural gas) and groundwater in certain aquifers are all non-renewable resources. Amongst them few are discussed here.

Earth minerals and metal oresare present in enormous amounts in Earth's crust and their extraction occurs where they are concentrated by natural geological processes. The production of such fossil fuels generally take millions of years through subsidence of the tectonic plates and recycling of the crustand humanity will need to shift its reliance to other sources of renewable energy resources.

Coal, which is the major source of fuel, is most abundantly used fossil fuels. Carbon dioxide is one of the gases responsible for global warming. The environmental degradation and imbalance in the ecological surrounding is a result of excessive extraction[2].

Oil is mostly available in the middle-east countries while limited oil wells are available in Canada, North America and Bombay high. Oil usage causes massive air pollution having emission in form of harmful gases like carbon dioxide due to the combustion in vehicles [2].

Natural gas is a naturally occurring hydrocarbon gas mixture. It consists primarily of methane but commonly including varying amounts of other higher alkanes and sometimes a small percentage of carbon dioxide, nitrogen, and/or hydrogen sulphide.Natural gas is a cleanest form of fossil fuel used as a source of energy. It burns completely leaving no ashes and hence results in almost no pollution.

In last few years, CO_2concentration has only increased in the atmosphere. With so many problems and limitations non-renewable resources cannot be used for lifetime. The need of the hour is to look for some alternative sources of energy to protect our environment.

III RENEWABLE ENERGY SOURCES

Renewable resources are substituted by natural processes and forces insistent in the natural environment. Worldwide there are abundant renewable energy based projects that are undergoing to harness this energy as it is clean, replenished, sustainable and broadly available.

There are various technologies that have been developed to take advantage of solar energy. Some of them are Photovoltaic system, solar water heater, solar electricity through various collectors, dish engine systems, trombe walls etc. The main advantage of solar energy is that it can be easily installed by home and business users because it does not call for huge set up as in case of wind and geothermal power. Solar energy benefits environment as well. Though solar energy has drawbacks also. There are two major disadvantages of solar energy. First one is the availability of sunlight for the period of daytime only and second one is the high initial cost. It is highly location dependent. Solar energy is the single renewable resource with global potential to satisfy a 10-20 TW carbon-free

supply limit in 2050. A practical solar power potential of 600 TW (Estimates from 50 TW to 1500 TW) for a 10% efficient solar farm, at least 60 TW of power could be supplied from terrestrial solar energy resources[3].

Wind has energy due to air in motion and the devices which are used to harness this energy are termed as Wind Energy Conversion System (WECS).Wind power is presently being used extensively in countries like USA, Denmark, Spain, India and Germany. Europe accounted for 48% of the world's total wind power generation capability in 2009. In 2010 Spain became Europe's foremost producer of wind energy by achieving 42,976 GW-h. In 2015 wind power set up 15.6% of all installed power generation capacity in the EU and it generates around 11.4% of its power [4].

Geothermal resources comprise of thermal energy from the Earth's interior stored in both rock and trapped steam or liquid water. The steam and hot water produced inside the earth is efficiently used to heat buildings and to generate electricity.The International Geothermal Association (IGA) has reported that in India's perspective geothermal provinces are estimated to yield 10,600 MW of power. In spite of having good potential for geothermal energy generation there are no operational geothermal plants in India. With increasing environmental problems with coal based projects, India will need to start depending on clean and eco-friendly energy sources in future; one of which could be geothermal[5]. Being a renewable source it is a reliable and cheap source of energy available 24 hours per day unlike solar energy. Its availability is independent of weather conditions. No extra storage facility is needed as it has inherent storage feature. Geothermal power plants require lesser land area as compared to solar power station. On the other hand, it has crucial drawbacks also. It is site specific means there are not many places where geothermal power plant can be stablished. Continuous extraction of heated ground water may lead to subsidence of ground water level. Geothermal fluid also brings dissolved gases and solutes with it which leads to air and land pollution. Drilling operation creates noise pollution in that particular area. The available thermal energy can't be distributed easily over long distances. Corrosive and abrasive geothermal fluid reduces the life of steam turbine and hence of the plant.

Biomass incorporates all organic matter existing on the earth's surface produced by photosynthesis. It can be transformed into thermal energy, fuels (liquid, solid and gaseous) and other chemical products with the help of various conversion processes. The prominent biomass technologies are comprised of direct combustion, biochemical and thermochemical conversion. Being an abundant, secure, environmental friendly and renewable energy source, biomass does not add carbon dioxide to the atmosphere as it engages the same extent of carbon in growing as it releases during consumption as a fuel. But **l**ike all other renewable energy sources, biomass energy sources are also site and factors specific.

Being the most abundant element, hydrogen is not often alone. It is frequently available with other elements and before using, it needs to be separated out which makes it quite expensive to extract and then store. Hydrogen has tremendous potential and can be used to power up homes, vehicles and space rockets. The main benefit of hydrogen energy is that it is environment friendly and by-product is only water. It can also be used to make bombs as it is highly inflammable in nature.

Hydroelectric power stations capture the kinetic energy of moving water through dams and provide mechanical energy to turbines to give electrical output. Hydropower is renewable, endless, liable and manageable source of energy. They are environment friendly as they do not emit any greenhouse gas. Only drawback is, they may cause adverse effect on aquatic life. It can also reduce the flow of water which may affect agriculture.

IV ENERGY FROM OCEANS

The electricity demand of the world can never be fulfilled to its full extent, however due to massive size of oceans, this energy can be used on much wider scale than the other alternative energy source. The ocean waves and tides that hit the sea shore have enormous potential in them to give energy output. If they are harnessed with full capacity they can go a long way in reducing world's energy problems. Presently there are very limited ocean energy power plants and most are fairly small.

From the oceans we can harness thermal energy from the temperature difference of the warm surface water and the cool deeper water, as well as potential and kinetic (usually put up with as mechanical energy) from the tides, waves and currents.

4.1 Tidal energy

The gravitational attraction due to Moon on Earth's surface causeoccurrence of phenomena called tides. The energy associated with tides can be used to produce power using various methods likeTidal stream generator,Tidal barrage,and dynamic tidal power and Tidal lagoon.

There are many benefits that are associated with use of tidal energy. The most significant of them all is:

- It is a renewable, eco-friendly and inexhaustible source of energy.
- Tidal power plant doesn't require any kind of fuel to run.
- A huge amount of energy from tides can be used for generation of electricity.
- Tides are active throughout a year.
- The life of tidal energy power plant is very long.
- Efficiency of tidal power is as high as 80% as compared to other resources like oil and coal[6].

There are many issues or disadvantages related with tidal power. The first negative point is the plant's high cost. The locations ideal for the constructionare local to coastal regions. The aquatic life is adversely influenced. The generation is for a small span of time as tides only occurtwo times in a day.

4.2 Ocean Thermal Energy

In Ocean thermal energy conversion (OTEC) energy is extracted using the difference in temperature as the basis between deep and shallow waters. The OTEC Plants can be located on ocean shelf, land or floating platforms. The advantages of the system are as follows:

- Power obtained from the OTEC system is continuous, renewable and pollution free.
- Unlike other forms of solar energy, output of OTEC shows very little daily or seasonal variation.
- Drawing of warm and cold sea water and returning of the sea water, close to the thermocline, could be accomplished with minimum environment impact.
- Electric power generated by OTEC system could be used to produce hydrogen.
- Tropical and sub-tropical island sites could be made free from pollution caused by conventional fuels for electricity generation.
- OTEC system might help in enrichment of fishing grounds due to the nutrients from the unproductive deep waters to the warmer surface waters.
- A floating OTEC plant can generate power even at mid sea and can be used to provide power for off shore mining and processing of manganese nodules.

Contrary to this due to small temperature difference in between the surface water and deep water, conversion efficiency is very low about 3-4%. Low efficiency of these plants coupled with high capital cost and maintenance cost makes them uneconomical for small plants.

4.3 Wave Energy

Wave energy is an asymmetrical and oscillating low frequency energy source that can be converted to a 50 Hertz frequency and can then be added to the electric utility grid. Waves gather, store and transmit this energy thousands of kilometers with a minute loss. Though it varies in intensity, it is accessible twenty four hours a day all around the year. Its net potential is better than wind, solar, small hydro or biomass power.

The ones which are derived from solar energy are the most common type.On the other hand the earth surface is heated by the sunvarious zones of different pressures are generated which produces winds. The friction that gets produced between the water and the flowing wind leads to formation of the waves (fig. 1).

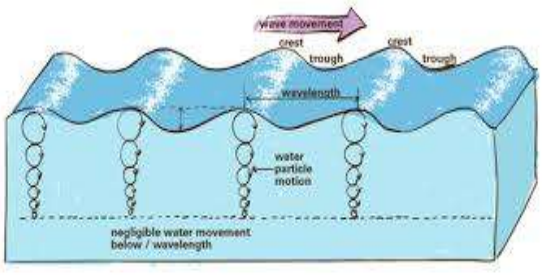

Figure 1: Water particle movement in waves[Adopted from www.franklincsd.org]

Many systems have been developed till now to harness wave energy. Some unique ways to harness energy are as follows:

The Pelamis System: The system looks like a snake in the sea. In this system empty segments are floated at a place where water depth is more than 50 m. Hinged joints are used to link the segments with each other. The generation of energy takes place when the length of the system is run over by waves. As the waves move up and down, movement takes place between each section which causes electricity to get produced.

Figure 2: Pelamis wave energy converter[Adopted from www.buildipedia.com]

Wave Dragon: The wave dragon is a system that momentarily stores water in a reservoir before falling into a turbine to produce electricity. The ramp is being used by the waves to transit to the reservoir. A source is used to release the water after it goes through an alternator.The complexities of the design (requires adaptation of mooring system, optimization of overtopping, reducing the effect of wave force). Here the motion is not used but directly the potential energy of waves. However sturdiness is one of the several advantages of this system. The device can directly be set up in ocean zones where waves with high potential is found.

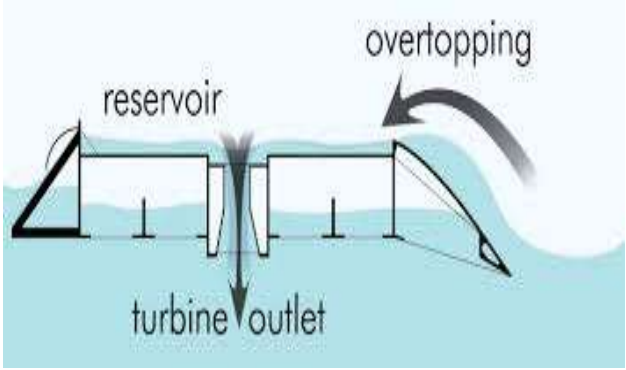

Figure 3: Typical wave dragon [Adopted from www.wavedragon.net]

The Archimedes Wave Swing (AWS):A cylindrical buoy which is moored on the seabed is the AWS wave energy converter. The principle of the float forms the basis for working procedure. The air-filled floater is the only moving part. Waves go up and down due to pressure applied on the floater which is located in a fixed cylinder at lower position.

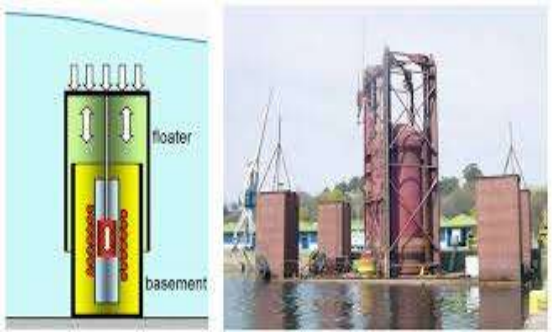

Figure 4: Archimedes Wave Swing[Adopted from www.intechopen.com]

The Power Buoy: The system consists of a submerged buoy). In the interior of the buoy, the wave rise and fall movement to output energy is tracked bythe piston. An underwater cable is used to transmit electricity to shore. The buoys are designed to be installed one to five miles (8 km) offshore in water 100 to 200 feet (60 m) deep.

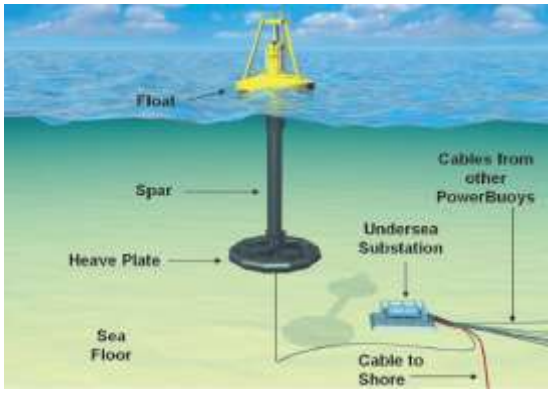

Figure 5: The power buoy schematic diagram[Adopted from www.renewableenergyfocus .com]

The Oscillating Water Column (OWC): The oscillating water column (OWC) or terminator comprises of an air capture chamber over the surface of the ocean. Whit the entry of the wave the air pressure in the chamber increase or decrease due to change in water level. The air compressed in the chamber rotates the turbine which in turn is connected to generator for producing electricity.

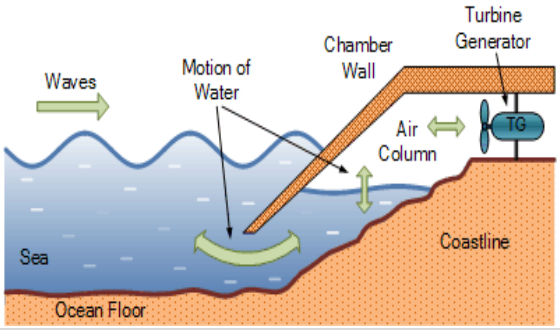

Figure 6: OWC schematic diagram [Adopted from www.alternative-energy-tutorials.com]

The pressure of the air forms the basis of the working of the device. The level of water in this cavity decides the pressure of air in it. The lower the water level is, the smaller is the pressure of air . There are two phenomena occurring in the oscillating water columns. Firstly the air present in the chamber is compressed by the rising water waves entering into the chamber. This compressed air causes the blades of the turbine to rotate. Now the wave falls down in the chamber. This retreating wave sucks air back into the chamber. Due to this suction the turbine blades rotate in the opposite direction resulting into the reduced efficiency.

To avoid this problem, wells turbine is provided in OWCs. The Wells turbine, is a bidirectional turbine that uses symmetrical aerofoils (fig. 6). The aerofoils spins in the same direction regardless of the direction of airflow. As water rises and falls around and inside an OWC, air is displaced by the water in the chamber and pushed back and forth past a power take off (PTO) system. These PTO systems allow the continuous generation of power due to the bidirectional wells turbines.

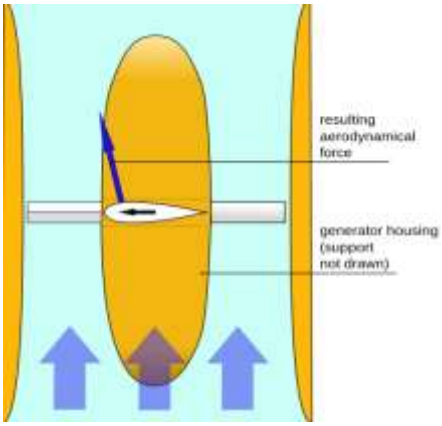

Figure 7: Wells turbine schematic diagram [Adopted from www.alternative-energy-tutorials.com]

The main features of wells point are as follows:

- It has no moving parts other than the main turbine rotor, making it easier to maintain and more cost effective.
- Its efficiency is lower than that of a turbine with constant air stream direction and asymmetric aerofoil. One reason for the lower efficiency is that symmetric aerofoils have a higher drag coefficient than asymmetric ones, even under optimal conditions. Also, in the Wells turbine, the symmetric aerofoil 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. A high angle of attack causes a condition known as "stall" in

which the aerofoil loses lift. The efficiency of the Wells turbine in oscillating flow reaches values between 0.4 and 0.7[7].

V CONCLUSIONS

- Energy generation from tides comes with high cost of these plants. The locations ideal for the constructionare local to coastal regions. The aquatic life is adversely influenced and can disrupt migration of fish. Also, the actual generation is for a short period of time since the tides only occur twice a day.
- OTEC plants, due to small temperature difference shows very low conversion efficiency about 3-4%. Low efficiency of these plants along with huge capital and maintenance cost makes them uneconomical. OTEC plants works well where the difference in ^{o}Fis 40.
- Generation of energy through ocean wave using wave dragon requires optimization of overtopping, adaptation of mooring system unnecessarily complicating the design of the system.
- During retreating of waves the air is sucked back into the chamber in Oscillating water column. Due to this suction the turbine blades rotate in the opposite direction which results into reduction in efficiency.
- Usage of well turbine leads to high angle of attack of wind which leads to a condition known as "stall" in which the aerofoil (turbine blade) loses lift. The efficiency of the Wells turbine in oscillating flow then further reduces.
- There is a need of the system which separates the effect of suction on the turbine blades. This could very well be facilitated if two non-return valves can be fitted into the chamber where the air gets collected. This would definitely reduce any effect on the turbine blades during facilitating the suction of more air.By applying this state of the art technique the plant could be run with the simple turbine itself. The power available and the efficiency is likely to be higher than the existing techniques.

REFERENCES

[1] Rodrigues, L., "Report on wave power conversion systems for electrical energy production", Department of Electrical Engineering, Faculty of Science and Technology (Nova University of Lisbon) 2829-516 Caparica - PORTUGAL

[2] http://www.conserve-energy-future.com/NonRenewableEnergySources.php [Last Visited on 12-05-2016]

[3] Smalley, R.E., (2005), "Future Global Energy Prosperity: The Terawatt Challenge," Materials Research Society (MRS) Bulletin, Vol. 30, pp. 412-417, www.mrs.org/publications/bulletin Orhttp://smalley.rice.edu/

[4] http://www.renewableenergyworld.com [Last Visited on 12-05-2016]

[5] https://en.wikipedia.org/wiki/Geothermal_energy [Last Visited on 12-05-2016]

[6] https://en.wikipedia.org/wiki/Tidal_power [Last Visited on 12-05-2016]

[7] https://en.wikipedia.org/wiki/Wells_turbine[Last Visited on 12-05-2016]