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REVIEW OF WAVE ENERGY HARVESTERS

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Abstract. Nowadays modern technologies are harvesting wave energy in various and ingenious ways using latest techniques and technologies. Wave, tides and currents form a natural part of abundantly available energy which can be harnessed as a substitute for oil & coal to meet our energy demands. This paper will present actual harvesters and practices to obtain energy from sea.

1. Introduction

In order to reduce CO₂ emission on the planet and to have a safe environment for us and our future it is important to find all possible ways to prevent and reduce air pollution. Due to present global energy demand numerous power plants have been built which consume fuels like coal, oil, natural gas or biomass. All of this contributes to nearly more than 42.5% of global CO₂ emissions. Of this, 73% can be attributed to coal-fired power plants, which emit 950 grams of CO₂ for every kilowatt-hour of electricity they generate, compared with 350 grams for gas-fired power plants. For power plants that run on renewable energies, such as hydro, wind, solar PV and solar thermal, the only CO₂ emissions are attributable to their construction.

Accordingly, for every kilowatt-hour of electricity generated, a solar PV system "emits" between 60 and 150 grams of CO₂ (depending on where the solar panels were manufactured), a wind turbine between 3 and 22 grams, and a hydropower plant 4 grams. As for nuclear power plants, even after the future need to dismantle aging facilities is factored in, CO₂ emissions still only represent 6 grams per kilowatt-hour of electricity generated – a stark contrast with the 950 grams emitted by coal-fired power plants.

Global research is presently focusing on harnessing the abundantly available energy generated naturally by water waves. Research shows that Wave Energy Conversion devices (WEC) have the lowest impact of CO₂ global emission and together with wind turbine, presents a future solution for minimizing the CO₂ emission in keeping with our ever growing energy demand.

Until now some WEC have already been tested and some of them are presently being used for power generation. WEC devices use kinetic energy generated by waves to move (rotate/oscillate) a prime mover coupled with an alternator to produce electricity. Most of these devices are presently located in North Sea given the areas weather condition, conducive for abundant wave generation.

2. Types of WEC devices

The types of WEC devices are further divided, varying depending on the wave motion which they convert. Mentioned as follow:



1. Wave profile devices

a) The device present in Figure 1. has two unites as illustrated in Figure 2. & Figure 3. with a one way clutch gearbox, a pinion and recoiling mechanism, spring for temporary energy storage and the generator. The waves rock the buoyant platform on which two WEC units are installed functionally opposite. This construction enables to capture the kinetic energy from every single wave. The kinetic energy amassed is stored in by means of a rotational energy spring, which when coupled to a generator with help of a gear box can be used for energy generation

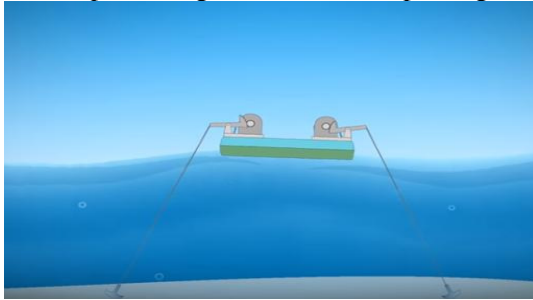


Figure 1. WEC device

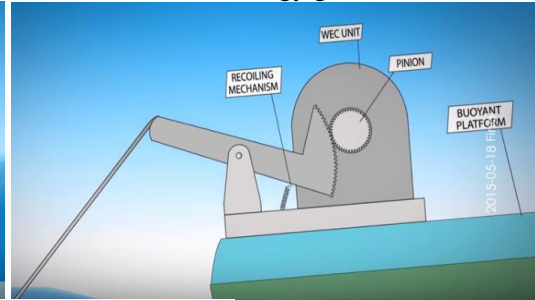


Fig 2. WEC unit

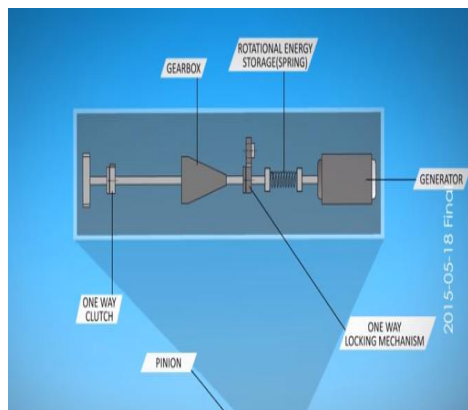


Figure 3. WEC components

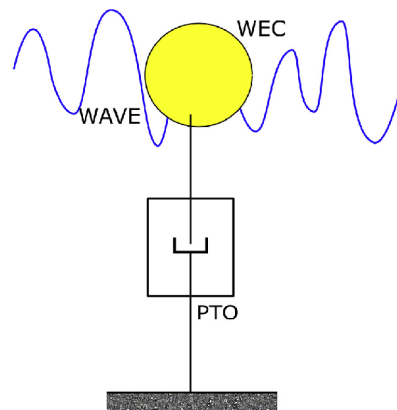


Figure 4. WEC general motion

b) The famous Pelamis (Figure 5.) – Is developed by a Scotland based company named “Pelamis Wave Power”. It floats on the water surface faced towards oncoming waves, as the waves hit the device its segments move. These segments due to motion of the waves move horizontally and vertically. In between the segments is a power module (Figure 6.). Waves cause the modules and tubes to move in relation to each other, this motion is resisted by hydraulic rams in each of the joints. The hydraulic rams pump high-pressure oil through hydraulic motors, which drives the electrical generators to produce electricity for greener markets and green economy. This wave attenuator device was first of its kind WEC to be implemented for commercial use and has a capability to power 500 homes per unit.

The drawback of this device is, it is only suitable for heavy weather condition. Light wave/wind condition will have little impact on the device thus rendering it unproductive.

The length of Pelamis is around 140m and 3.5 m diameter with a power rate of aprox. 750 kW.



Figure 5. Pelamis

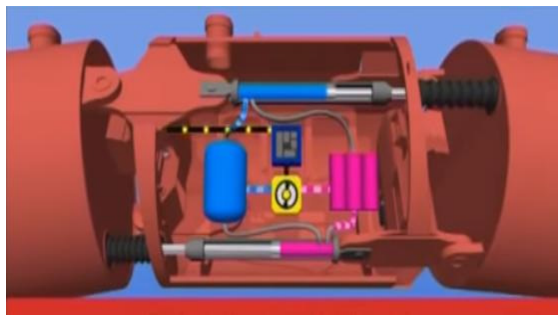


Figure 6 Pelamis modules joined

c) Searaser (Figure 7.) – The system uses free floating buoys, anchored to the sea bed (Figure 8). The buoys are attached with basic piston pumps which due to the movement of the wave pump sea water to an artificially created reservoir. The water from this reservoir is then used to produce hydro-energy by controlled release of water over a turbine which is coupled with an alternator. The virtual presentation of entire system is shown in Figure 8.



Figure 7. Searaser virtual presentation



Figure 8. Searaser in real waves

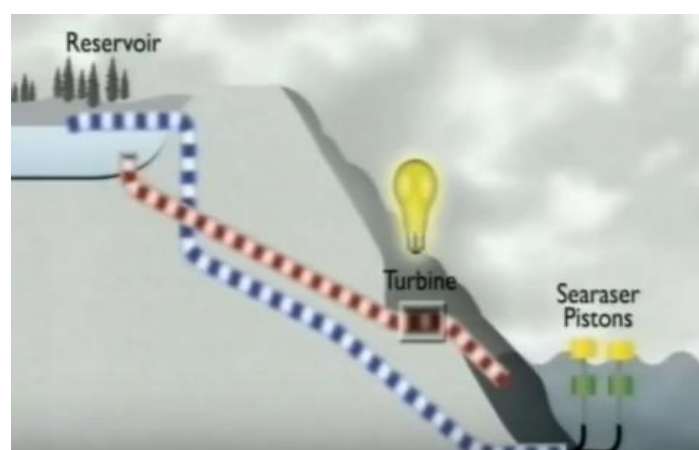


Figure 9. Searaser system presentation

d) The below devices (Figure 10) generates energy by moving a permanent magnet inside wire wound metal coils as shown in right side of Figure 11. The permanent magnet moves together with the buoy which floats on the sea surface and moves vertically due to waves. The movement

of the permanent magnet between the coils produces varying magnetic field thus by laws of induction produce electric energy. A longitudinal section of the device is presented in Figure 11. The drawback with this device is under gentle rolling or light wave condition the movement is not ample to produce energy.

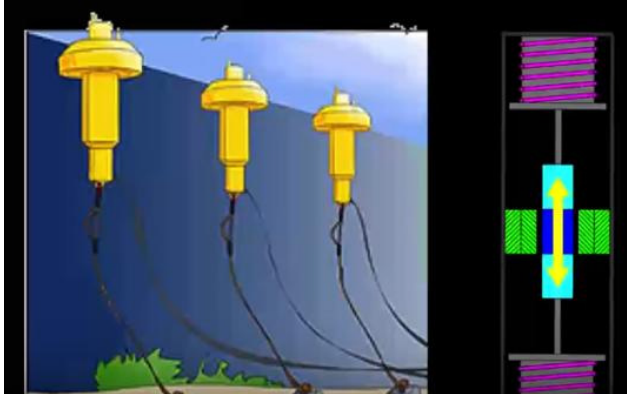


Figure 10 Magnet induction buoy

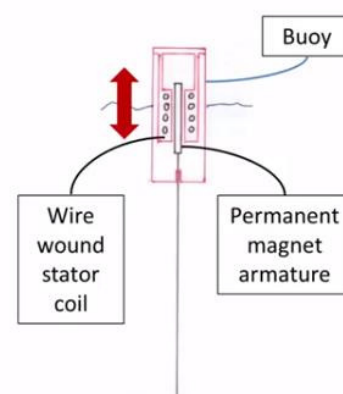


Figure 11. Longitudinal section

e) The Power Buoy PB – 150 (Figure 12) is under development and is generating energy by moving up and down with the waves. It comprises of a long bar (spar) which is anchored using a heavy plate. A free floating buoy is attached to the spar, wave motion moves buoy over spar as shown in Figure 13. which act on hydraulic cylinder to pressurize and pump hydraulic fluid. Hydraulic fluid then drives hydraulic motor coupled to a generator.

The PowerBuoy is designed for wave height range between 1 and 6 m. The Buoy locks in place on spar for higher wave heights to prevent damage.

This WEC was tested in North Sea and produced power of 45 kW from wave heights of 2 m.

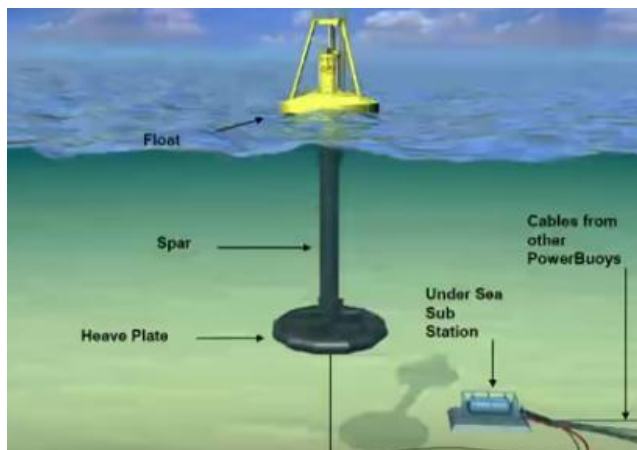


Figure 12. Power Buoy

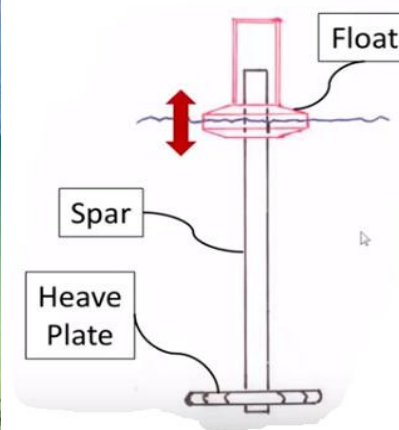


Figure 13. Power Buoy section

f) The famous Oyster (Figure 14)- Harnesses the motion of the waves to pump sea water in a controlled fashion to drive a turbine. The vertical construction moves back and forward with the waves and the piston pump arrangement pumps the pressurized seawater to the shore where a turbine is driven by controlled release of this pressurized sea water.

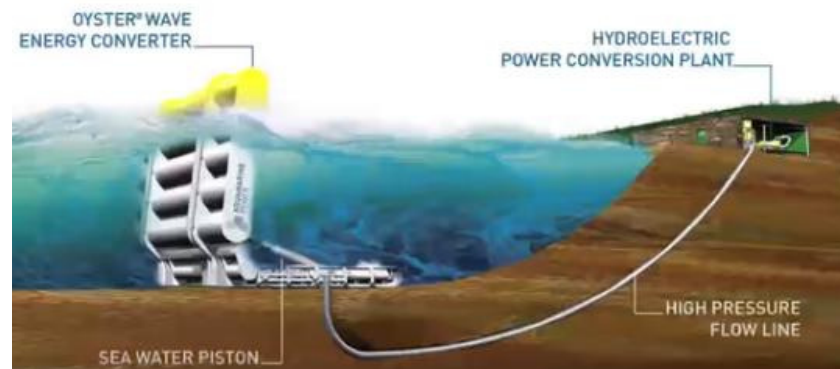


Figure 14. WEC Oyster

In the same way Wave Roller (Figure 15.) are bending back and forward with the waves and pumping pressurized sea water to the land.



Figure 15. Wave Roller

g) The device presented in Figure 16 is installed on land next to a breakwater. It comprises of 2 paddles which move with the waves, generating a movement in the two hydraulic pumps. This hydraulic oil is then used to drive a prime mover coupled to an alternator.



Figure 16. Wave paddles

“Wave Star” (Figure 17.) works on the same principle as explained above. The device is designed to convert kinetic wave energy into electricity, is equipped with kinetic-energy harvesters called floats, these floats oscillate due to motion of waves which is transmitted through the hydraulic piston to power generators. In case of storm the floats can be lifted to a safe position.



Figure 17. Wave Star

3. Oscilating Water Column

a) Ocean Linex (Figure 18) – It comprises of a sealed chamber open only at the bottom to the sea which allows waves to enter. The movement of sea (waves) causes the air inside the chamber to compress causing pressure variation which when release over a turbine can be used to produce energy.



Figure 18. Ocean Linex

b) Another project is to construct a wave power station on-shore, by constructing a chamber open on the sea side which allows water to flow inside the chamber as shown in Figure 19. The principle of creating energy is similar to “Ocean Linex” as presented above. Air is forced forward and backwards together with the waves in the chamber. This compressed air when directed over a multi-directional turbine coupled to an alternator using a gearbox can be used for energy generation as illustrated in (Figure 20.). The first power station like this was created in 2000 on a Scottish Island – Islay, named Limped 500 with a capacity on 0.5 MW.



Figure 19. Power Station



Figure 20. Air turbine

4. Wave capture device

In this category the most commonly known device is “Wave Dragon” as shown in Figure 21 and Figure 22. Waves approach to the device guided by 2 wave reflectors as shown in Figure 21. The platform on the center is acts as a ramp to push water in the central reservoir as can be seen in Figure 22. From the central reservoir the water is flows through several hydro turbines (Figure 23), the water spins the turbine and the energy is converted into the electricity by means of an alternator coupled to the turbine. The device is sturdy enough to combat rolling and pitching and allows huge waves to pass over the rig. The “Wave Dragon” is already in use since March 2003 in Denmark in Nissum Bredning.

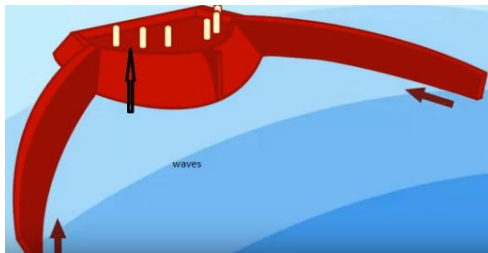


Figure 21. Wave Dragon, frontal view

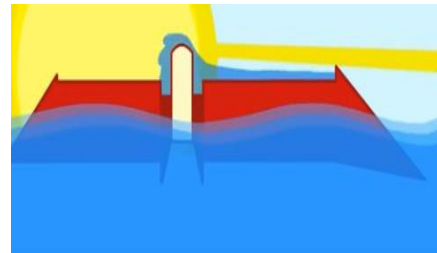


Figure 22 Wave Dragon, side view

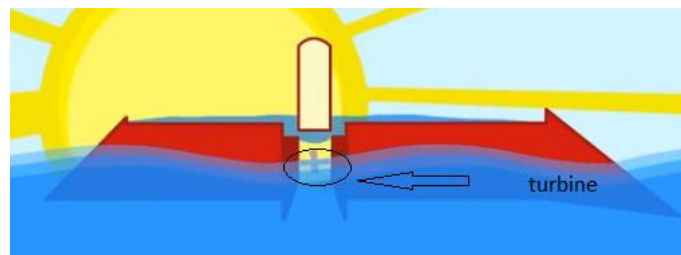


Figure 23 Water turbine

5. WEC statistics and distribution

A statistic done in 2018 worldwide regarding usage of wave energy converters show:

Country	Planned	Installed	Operational	Total
Canada	0	0	11	11
New Zealand	0	20	0	20
Denmark	39	12	1	52
Italy	0	150	0	150
Mexico	200	0	0	200
Ghana	0	0	450	450
Spain	0	230	296	526
Korea	0	0	665	665
China	0	400	300	700
Portugal	350	0	400	750
United States	1335	500	30	1865
Sweden	0	0	3200	3200
Ireland	5000	0	0	5000

As we can see only few countries have operational WEC, due to their geographic location and ability to install such devices on their shorelines. The areas which have a lot of wave generation

are shown in Figure 4, here the efficiency is at maximum level but also as we saw in this document all of WEC have certain limitation due rough sea and storm. We can conclude that for using this device the importance is the technology used and the design. For example in Turkey, Eregli, with detailed wave profile study have developed a device to harness wave energy by construction of an Oscillating Water Column (2014). As presented above the WEC can convert any kind of wave movement in energy (up and down, side to side), the challenge is to make them more efficient and to adapt for the area.

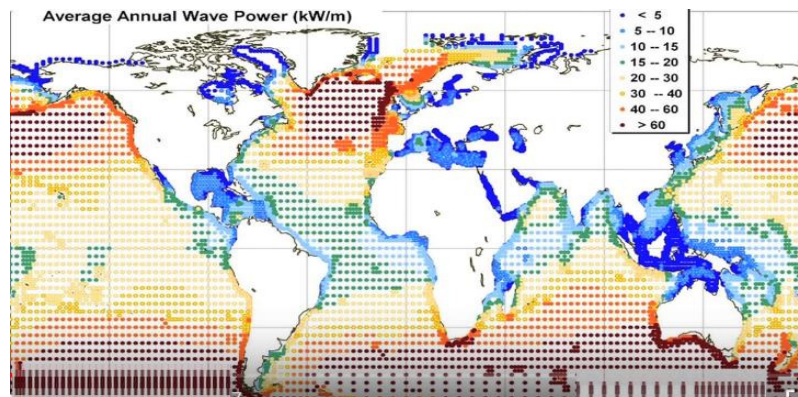


Figure 24 – Wave Energy around the world

At present only 10MW is produced from ocean energy, out of total 2.1TW which is consumed worldwide, that meant 0.0005% only. In the Figure 25 you can see what the percentage contribution of various power plants presently in service.

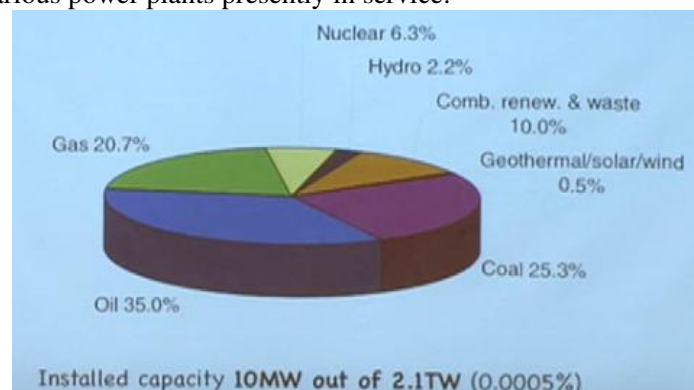


Figure 25 – Energy Providers

6. Conclusion

The research for converting wave energy in electrical energy is not new. The first document was published in 1799; oceans energy was in the olden days used to power navigational buoy.

Since the planets energy reserves are dwindling with time and CO₂ emission are on a continuous rise, the research for renewable energy and emission reduction is continuously developing. Like solar power, wind and wave energy is available to us in abundance as they form an integral part of Earth climate and life form support. The aim is to advance the research in design and development of WEC which are more efficient and conducive to work under various wind and wave condition.

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