Technium EcoGeoMarine
Technium EcoGeoMarine Vol. 2, pp.1-9 (2023)
ISSN: 2971-8112
www.techniumscience.com

# A REVIEW OF WAVE ENERGY CONVERSION WITH POINT ABSORBER CONVERTERS

**Ionuț Cristian Scurtu, Bianca Ioana Mîndroiu Romeo Boșneagu, Isac Hristache**

„Mircea cel Bătrân" Naval Academy, 900218 Constanta, Romania.

**Abstract**
This study aims to expose the role of point absorber converters and how these converters use wave energy to create electricity. Starting from general information about converters, the study aims to classify them according to constructive criteria and define the mode of operation of one point absorber converter. The provisions presented in this studio represent the current state of point absorber convertors, helping to understand and increase the utility of these equipment
**Keywords** Point absorber convertors, waves, renewable energy, hydraulic system, efficiency

## Introduction

According to the studies done by the International Maritime Organization, by 2050, the total decarbonization of the maritime sector is desired. Thus, in order to reach this point, it is necessary to use renewable energy sources, being the cleanest option, having 0 carbon emissions.

In the case of the maritime sector, the use of wave energy represents the most suitable source of renewable energy, having a great potential in the generation of electricity. This resource is considered to be less exploited, assuming that wave energy could statistically exceed the energy consumption.

Compared to other renewable energy sources such as wind or solar energy, the advantages of using wave energy are vast. Firstly, wave energy provides more power than solar or wind. Secondly, this renewable energy allows for more usage time, being available approximately 90% of the time. Lastly, the energy stocked from the waves presents a higher predictability in comparation with the other resources.

Wave energy is formed as a combination of solar and wind energy. Thus, the sun heats the air, this temperature change causing wind. Wind acting on the water surface creates waves. An interesting fact is represented by the density of this energy, being much higher because it results from the combination of the other two renewable energies. An advantage in the use of wave energy is represented by the integration of conversion devices with other renewable energy transformation equipment. To be as efficient as possible, these devices are small in size, managing to capture energy even from low-energy seas.

## Classification of point absorber convertors

Point absorber convertors are defined as floating oscillating bodies. They consist of a buoy and a fixed reference, oscillating body or seabed. Through a power take-off, the relative movement of a buoy relative to a fixed reference captures wave energy. Likewise in the case of a submerged oscillating body that becomes a two-body point absorber (Figure 1).

Figure 1 shows the classification of point absorber converters. Thus, they can be classified from the point of view of construction, installation or mode of operation.

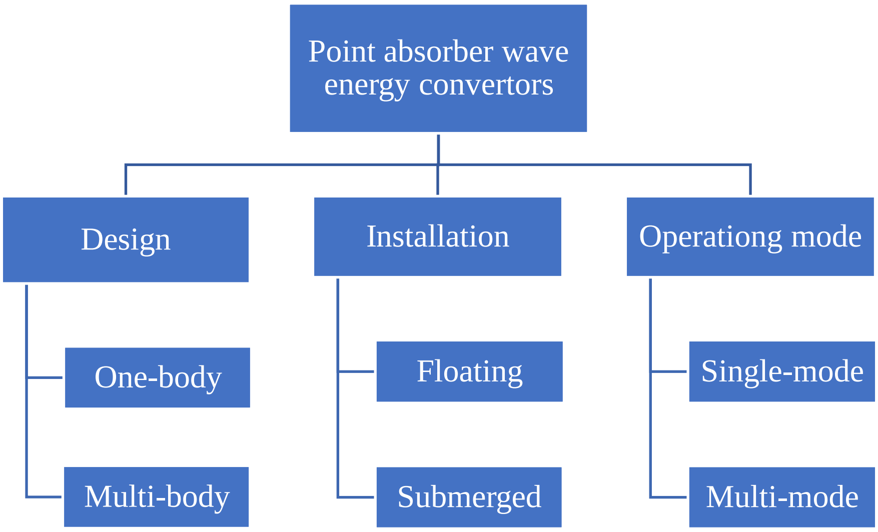


Figure 1 Classification of Point Absorber Convertors, *Source: Journal of Marine Science and Engineering*

Depending on how they were designed, they can be single-body or multi-body (Figure 2). Single-body converters captures the energy between the buoy and a fixed point. This point can be, for example, the bottom of the sea. Multi-body converters are defined by capturing the energy resulting from its movement between two bodies.

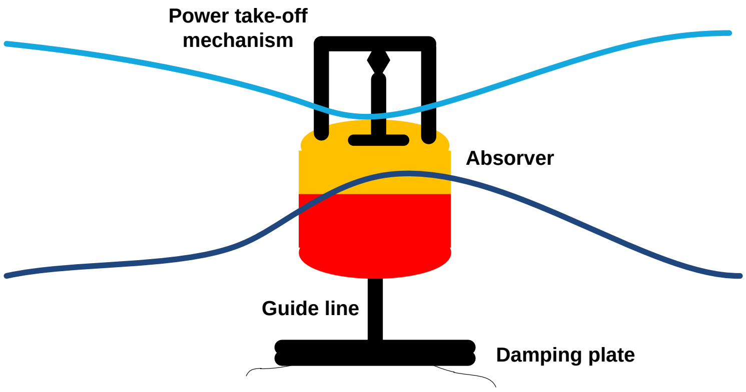


Figure 2 Single-body point absorber

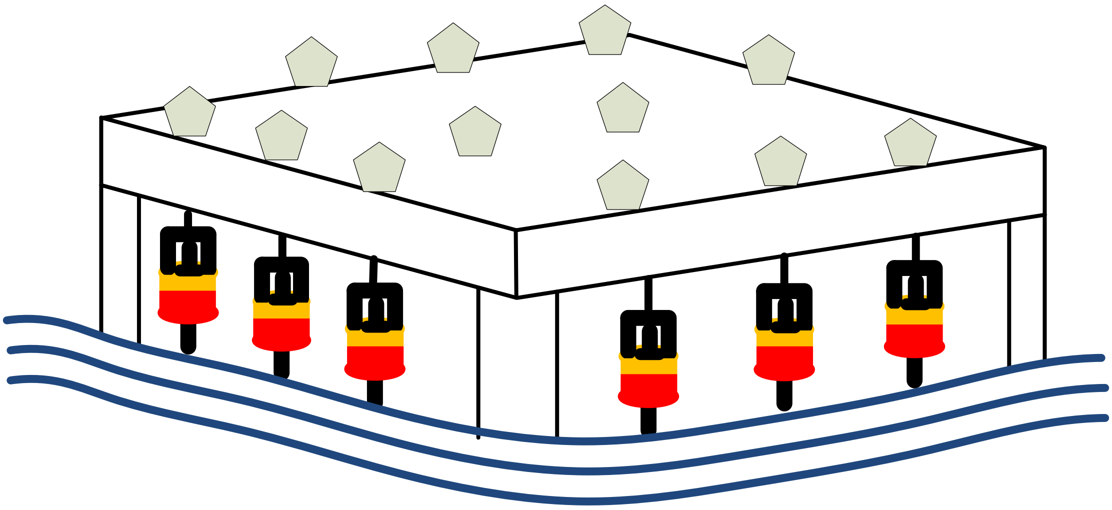

Figure 3 multi-body point absorber

Analyzing from the installation point of view, the converters can be floating or submerged (Figure 3 and 4). Floating converters are defined by a floating body, which interacts with the water surface and is anchored to the seabed. The captured energy is formed following the oscillations of the floating body in relation to the anchor point. Submerged converters capture energy similarly to floating converters, the difference being the positive buoyancy of the converter.

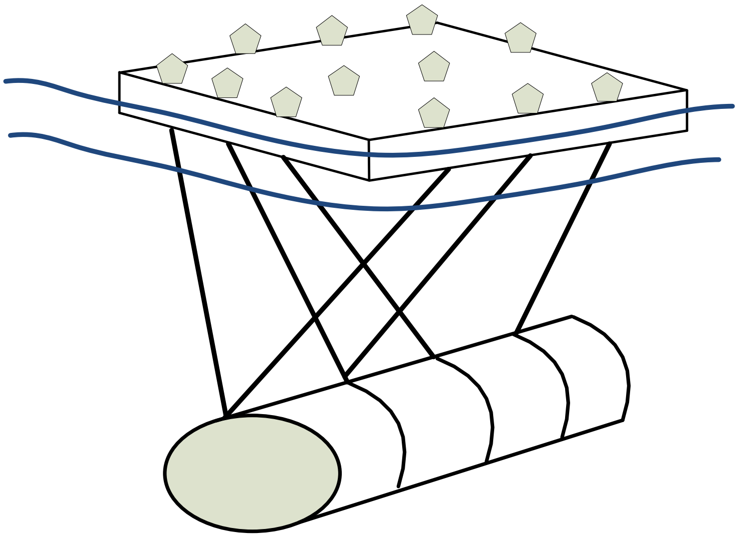

Figure 3 Floating point absorber converter

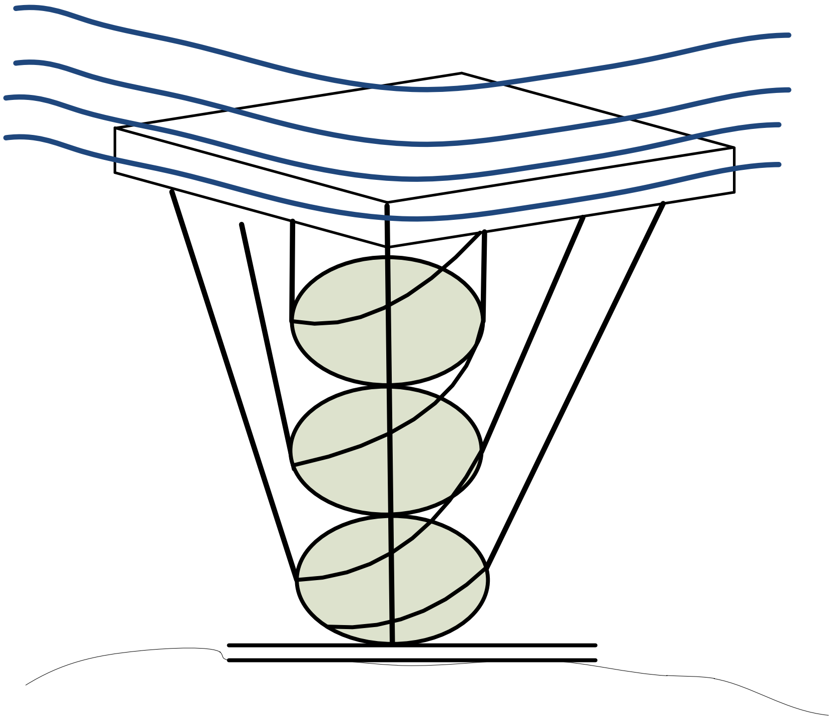

Figure 4. Point absorber convertor submerged

Discussing the mode of operation of converters, they can be single-mode or multi-mode. Single-mode converters are represented by a single point, while multi-mode ones are generally attached to a semi-submersible structure to which several floating bodies that capture wave energy are attached.

Depending on the area where these point absorber converters are located, opt for the most suitable according to the classification. If we are talking about rough water, or in general in off-shore areas, we go for the multi-body point absorber, in order to capture as much of the energy of the waves as possible. If we are talking about calm water, with few waves, it is recommended to use a point absorber submersible and single-body converter. Thus, the converter must efficiently capture the energy it transforms.

**Hydrodynamic modelling of point absorber converters**

One-point absorber converter is one of the most efficient wave energy conversion systems. It captures the vertical motion of the waves and converts it into electrical energy. The hydraulic PTO mechanism is the most mature one for wave energy conversion, comprising hydraulic cylinders, pipes, regulating valves, accumulators, hydraulic motors, rotary generators, etc (Guo *et al*, 2022).The design of the converter being a compact one, such equipment is used especially in the off-shore industry, having an increased efficiency (Figure 5).

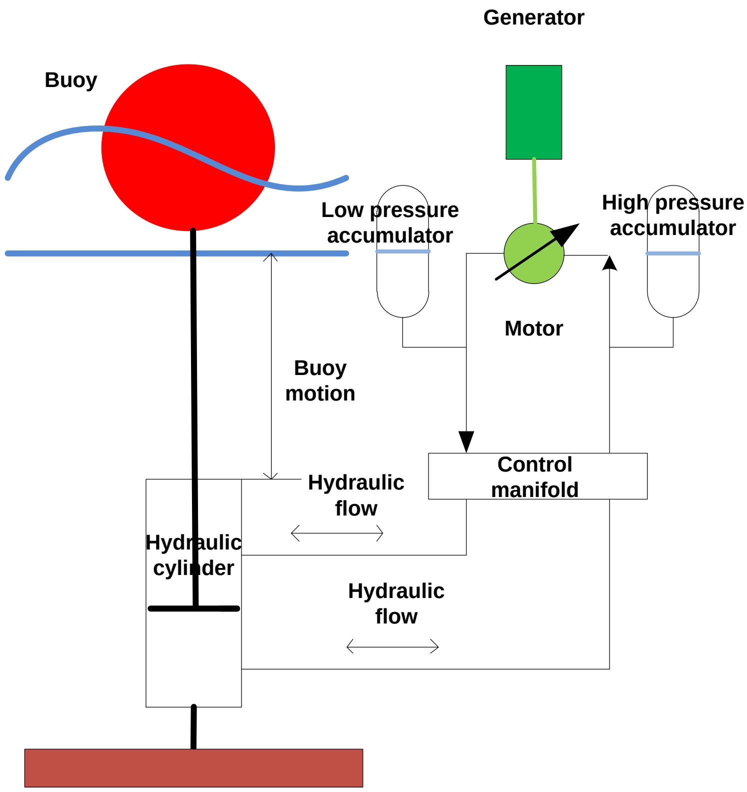

Figure 5. Functional scheme of the one-point absorber converter

One point absorber converter consists of float, power take-off system along with hydraulic and electrical circuits and control system. The float is positioned at the top of the equipment. The energy captured by the float from its moves, it is transferring to the conversion system.

The power take-off system converts the mechanical energy from the float into electrical energy. Into hydraulic circuits, the hydraulic pressure comes out from mechanical energy. The hydraulic cylinder

This process compresses the fluid within the hydraulic system, generating uniform pressure. In the third stage, the mechanical energy is further transformed into electrical energy. The hydraulic piston, previously set in motion by the float, activates a generator, producing electricity. The resulting current is alternating and has a variable frequency. To ensure stability, the fourth stage involves voltage and frequency regulation through electronic systems. An inverter and rectifier convert the fluctuating energy into a stable direct current. Once the electrical current is stabilized, it is either stored or distributed through the control system, which continuously monitors and optimizes performance. In the second stage, the movement of the float is converted into the mechanical force that acts on a hydraulic piston. Thus, the fluids in the system are compressed, forming an uniform pressure. In the third stage, mechanical energy is converted into electrical energy. Thus, the piston previously actuated by the float, activates a generator, producing electricity. The previously obtained current is alternating and its frequency is variable. From this point of view, it is necessary to stabilize the electricity, which is realized in the fourth stage. Electronic systems stabilize voltage and frequency. The inverter and rectifier transform the oscillating energy into constant electric current. Once constant electric current is obtained, it is stored and distributed through the control system, being at the same time monitored and optimized according to its performance.

**Implementation of Point Absorber converters in the North Sea. A case study: WaveEL**

Wave energy is a renewable energy source with great potential, especially in the northern regions of Europe, where maritime conditions are ideal for tapping this resource. A concrete example of the use of this technology is WaveEL, a system developed by Swedish company Waves4Power. This device has been tested and installed in the North Sea, demonstrating that it can convert wave energy into electricity with high efficiency.
Waves4Power – the company behind the WaveEL project

Waves4Power is a Swedish company founded in 2008 that specializes in developing systems that convert wave energy into electricity. It is based in Gothenburg, Sweden. The company's main goal is to reduce carbon emissions by creating sustainable solutions for clean energy production.

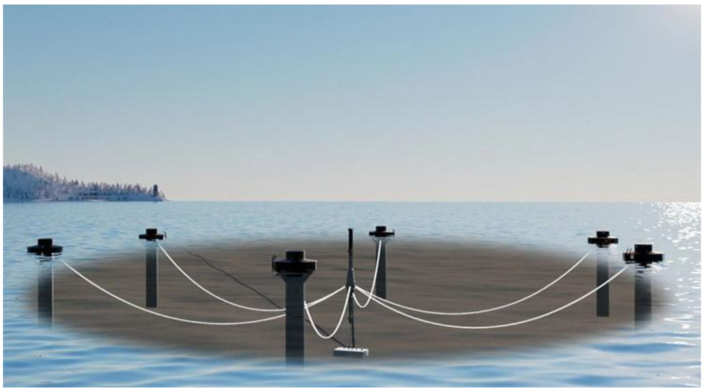

Figure 6. WaveEL working principle

The WaveEL system is a type of energy converter called a Point Absorber, which uses a vertical float to capture wave motion. This float is connected to a linear electrical generator through a mechanism called Power Take-Off (PTO), which converts the oscillatory motion of the float into electricity.
The vertical motion of the float is described by the fundamental equation of oscillations:

$$M\frac{d^2z}{dt^2} = -\rho gAD + \Delta p(z,t) - F_{\text{disipare}} - F_{\text{PTO}}$$

unde:

- $M$ – total mass of float, including mass of added water;
- $A$- cross-sectional area of float x
- $D$ – the float depth;
- $\rho$ – seawater density;
- $g$ – gravitational acceleration,
- $\Delta p(z,t)$ – pressure variation with position and oscillation time;
- $F_{\text{disipare}}$ – energy dissipation through radiation and friction;
- $F_{\text{PTO}}$ – the force exerted by the PTO system.

Technium EcoGeoMarine Vol. 2, pp.1-9 (2023)
ISSN: 2971-8112
www.techniumscience.com

The power generated by the PTO system is given by the relation:

$$P = F_{\text{PTO}} \cdot v$$

unde:
$P$ – power generated;
$v$ – vertical float speed. By optimizing the PTO system, WaveEL maximizes energy extraction according to varying wave conditions, thus improving conversion efficiency.

Implementation and performance in the North Sea
In February 2016, the WaveEL system was installed near the Runde Environmental Center in Norway. This was the first grid-connected wave energy project in Norway with a capacity of 100 kW. The system was anchored to the seabed and connected via a submarine cable to the terrestrial grid.

Figure 7. *WaveEL in the North Sea*

Experimental data and performance
Tests have shown that WaveEL can operate effectively in waves of 1.5 - 5 meters in height and with a period of 6 - 10 seconds. Below are some values measured during testing:

| **Parameter** | **Value** |
|---|---|
| Frequency of float oscillations | 0,1 – 0,3 Hz |
| Average power generated | 50 – 200 kW |
| Efficiency of the PTO system | 70 – 85% |

Advantages and limitations
Advantages

- high efficiency - the system can capture wave energy even in variable weather conditions;
- long lifetime - materials used are resistant to corrosion and mechanical stress;
- easy integration - WaveEL can be connected to existing offshore electricity grids.

Limitations

- ✓ high installation and maintenance costs - the equipment needs to be serviced regularly to keep it running optimally;

- ✓ efficiency dependent on ocean conditions - areas with small or irregular waves are not ideal for this technology;
- ✓ the need for an advanced PTO system - to extract as much energy as possible, the system needs to be constantly optimize.

WaveEL is a successful example of harnessing wave energy in the North Sea. Tests show that the system can provide stable and efficient electricity with high potential for large-scale deployment. As an environmentally friendly technology, WaveEL can become a viable alternative for reducing dependence on fossil fuels and developing renewable energy sources in maritime regions.

## Conclusions

Point absorber converters are becoming an increasingly better solution for the production of electricity from renewable energy. Having a high yield, this renewable energy source is ideal for exploitation in the maritime field. Thus, it is considered that this can be a solution for the total decarbonization of the maritime sector.

Among the advantages of using point absorber convertors, can be count the direct conversion of energy, having a high yield, the adaptability to different weather conditions and the easy integration of these systems into solar and wind systems.

From the point of view of disadvantages, the high costs for equipment maintenance stand out in particular. Being exposed to extreme conditions, their durability is affected, requiring early maintenance to extend their lifetime. At the same time, the efficiency of such a system depends on the type of water, so in areas with small waves, the efficiency of this system is low.

## References

1. Balazs C., Pavol B., *Wave energy converter concepts: design challenges and classification*, IEEE Industrial Electronics Magazine, 2012;
2. Bingyong G., Tianyao W., Siya J., Shunli D., Kunde Y., Yaminh Z., *A review of point absorber wave energy converters*, Journal of Marine Science and Engineering, 2022;
3. Elie A. S., Ran Z., Xu W., *Point absorber wave energy harvesters: a review of recent developments*, Energies, 2019;
4. Gunn K., Stock-Williams C., *Quantifying the global wave power resource*, Energy 2012;
5. Chiba S., Waki M., Wada T., Hirakawa Y., Masuda K., Ikoma T., *Consistent ocean wave energy harvesting using electroactive polymer (dielectric elastomer) artificial muscle generators*, Energy, 2013;
6. Ibarra-Berastegi G., Sáenz J., Ulazia A., Serras P., Esnaola G., Garcia-Soto C., *Electricity production, capacity factor, and plant efficiency index at the Mutriku wave farm (2014–2016)*, Ocean Eng, 2018;
7. Illesinghe S.J., Manasseh R., Dargaville R., Ooi A., *Idealized design parameters of Wave Energy Converters in a range of ocean wave climates*, Int. J. Mar. Energy, 2017;
8. Tampier G., Grueter L., *Hydrodynamic analysis of a heaving wave energy converter*, Int. J. Mar. Energy, 2017.
9. Bingyong Guo, et al., A Review of Point Absorber Wave Energy Converters, https://www.mdpi.com/2077-1312/10/10/1534, J. Mar. Sci. Eng. 2022, 10(10), 1534; https://doi.org/10.3390/jmse10101534.

10. Guanghua He, et al, Review on research approaches for multi-point absorber wave energy converters, https://www.sciencedirect.com/science/article/abs/pii/S0960148123011527?via%3Dihub, https://doi.org/10.1016/j.renene.2023.119237
11. Piofrancesco Barone, et al, Latching control of a point-absorber wave energy converter with a hydraulic power take-off system: A calabrian case study, https://www.sciencedirect.com/science/article/abs/pii/S0029801824021139, https://doi.org/10.1016/j.oceaneng.2024.118775Dapeng Zhang, et al, Wave energy converter with floating-point absorber and catenary mooring: dynamic coupling analysis, https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2024.1338330/full.
12. Dapeng Zhang, et al, Wave energy converter with floating-point absorber and catenary mooring: dynamic coupling analysis, https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2024.1338330/full.
13. Rathishchandra.R.Gatti, Ajith.B.S., Recent Trends in Point Absorber Wave Energy Converters, SAHYADRI INTERNATIONAL JOURNAL OF RESEARCH, VOL 4, ISSUE 2, 2018, https://tethys-engineering.pnnl.gov/sites/default/files/publications/december_2018_1.pdf.
14. Waves4Power. "The WaveEL™ System." https://www.waves4power.com/waveel/
15. Tethys. "Runde Waves4Power Project Full Scale." https://tethys.pnnl.gov/project-sites/runde-waves4power-project-full-scale
16. Waves4Power. "The first tests of wave power at Runde are now accomplished and the wave power buoy WaveEL™ 3.0 is towed to Fiskåholmen." https://www.waves4power.com/the-first-tests-of-wave-power-at-runde-are-now-accomplished-and-the-wave-power-buoy-waveel-3-0-is-towed-to-fiskaholmen/