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D.2.2 – WECs description and PTO base case characteristics

WP2:	Detailed model of the existing WECs including the PTO
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Statement of originality

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

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Glossary

PTO	Power Take-off
WP	Work Package
WEC	Wave Energy Converter
POM	PTO Optimization Model
CAPEX	Capital Expenditures
OPEX	Operational Expenditures

Executive summary

This document will gather all of the originally proposed reports D2.2, D2.3, D2.4 and D2.5: WECs descriptions with restrictions. PTO base cases characteristics.

In this document detailed information from WEDGE, CORPOWER, CENTIPOD and HYDROCAP respectively can be found regarding the description and restrictions of their own Wave Energy Converters.

This report will be updated in M33 based on the POM developed in WP2, and parametrized for each of the WEC devices with their characteristics and control strategy, WavEC will carry out a set of calculations for each of the 8 test scenarios defined in WP5.1 in order to evaluate the improvement achieved in each case with the new PTO solution.

1. Wedge Global

1.1 Technology description

The W1 is a floating-point absorber (WEC) combined with direct drive switched reluctance generator (PTO), it was initially deployed in 2014 in the Canary Islands and has been tested at the PLOCAN test site and Las Palmas harbor over the last 4 years.

The W1 is composed of two main bodies, the floater (1) moving up and down under the forces of the sea, and the spar (2) where the PTO is located, the spar is a floating body as well as the floater but can be considered static given the hydrodynamics of the geometry.

The float is in free vertical movement, so that it follows the oscillation of the waves (unless it is in the braking position). Inside of the floater there is water to act as a ballast tank. Attached to the float is the generator shaft which is inserted into the <<fixed>> part, the spar (2). The shaft transfers the motion of the floater to the translator of the generator, being the stator fixed to the spar this generates a relative movement between stator and translator.

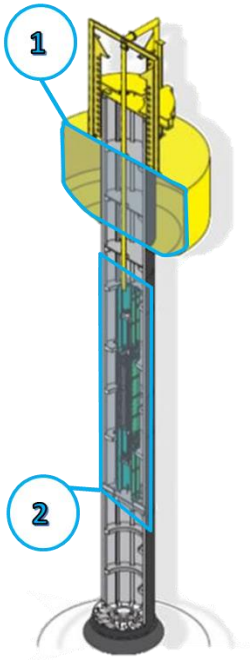

Figure 1. W1. 3D Model.

The spar is the fixed part of the device (it is not really fixed but the movements relative to those of the float are considered negligible). Levels -1 to -3 are for control and electronic cabinets, levels -4 to -7 are for PTO installation, from level -8 to the bottom (heave plate) are ballast tanks. At the bottom of the spar we have a bilge pump. Access to this pump for maintenance is guaranteed in a safe manner.

1.2 PTO restrictions

Here a set of PTO design criteria's will be analyzed to be considered in the design process affecting housing and electronics. Possible restrictions include:

- Mechanical: If the forces or speeds to be handled in the device jeopardize the structural integrity of the device as a whole or any of its components. For Sea-Titan project a maximum velocity of 3 m/s and a maximum force of 200kN are considered, as so, this restriction doesn't apply for Wedge Global technology, the WEC structure and components are designed to hold the necessary forces and velocities in a safe manner.
- Electrical: If the electrical components are not able to withstand the operational currents and voltages of the device in operation. For Sea-Titan project a maximum current of 300A is defined as well as a DC voltage of 1000V, the electrical components will be designed if need taking into account this consideration in a safe manner.

- Geometrical: The housing of the PTO is a key aspect when defining the design of the modular and crosscutting PTO, each technology developer has his own design which could affect the final shape of Sea-Titan PTO. For Wedge Global this limitation does not affect the length of the PTO, but it does affect the width, since the PTO is inside the part called spar (submerged) which must be as slim as possible. This limitation is currently at 1400mm because of security reasons (accessibility) but can be adapted in future design if needed.

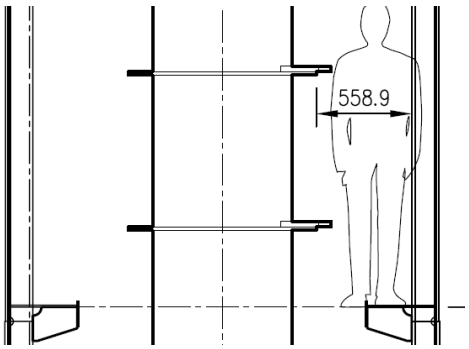

Figure 2. W1. PTO Housing. Accessibility.

1.3 Improvement achieved with the new PTO solution

To be updated in month 33 based on a set of calculations carried for each of the 8 test scenarios defined

2. HYDROCAP

2.1 Technology description

Seacap is an oscillating wave energy converter buoy (a point absorber), moving up and down, under the forces of the sea, around a monopile fixed to the seabed. It features a dry and large utility deck, of about 250 sqm, 15m high above sea level, for operations and airgap safety. The deck supports electrical control command and power conversion equipment, in marinized and standardized ocean-going containers. It may also accommodate other equipment such as hydrolysers and compressors or else.
The kinetic energy generated by the heave, activating the floater up and down, is directly converted into electricity thru linear generators placed between the floater (moving point) and the deck (fixed point). This system, modular and robust, has been designed to cope with a wide range of weather conditions and can be safely and automatically disconnected and docked in case of extreme weather.
As a brief description of the system shown, the main modules appear successively from the deck thru the water level and down to the foundation:

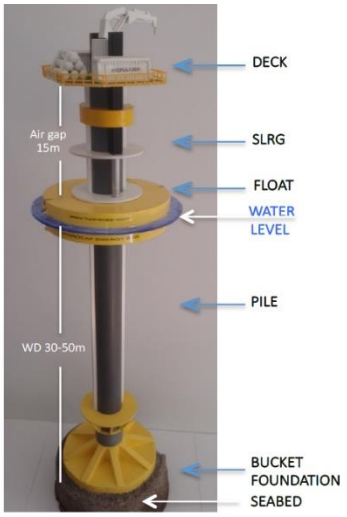

Figure 3. Seacap. Scale model

2.1.1 Conversion deck and utility platform

Besides the primary objective of dry-housing the control and electrical conversion containers, the deck is also available for housing other applications, in particular hydrolysers for the production of di-hydrogen (H2), compressors and mobile tanks and a utility crane for their periodical shipment to the energy markets.

2.1.2 PTO Linear generators

The heart of the system, the PTO, is composed of two or more direct drive linear generators, eliminating the high cost of permanent magnets, linear to rotary transformation, or hydraulic systems, main causes all together of important industrial and economical losses.

2.1.3 Floater and monopile

Made of two identical parts, easy to install or remove at sea, the floater also features ballast and quick disconnect/connect systems for safety submersion in case of stormy weather conditions.

2.1.4 Bucket foundation

Induces important costs reduction and environmental advantages such as the absence of catenary anchors or installation noise, reversibility of operations, easy relocation and recycling, compared to massive fixed gravity base solutions.

The technology has been conceived and developed from live offshore operational experience, in full knowledge of environmental constraints and costs, therefore having always in mind the safety of persons, if any, for maintenance, the survivability of the equipment's, their CAPEX and OPEX, their operational efficiency and their minimal impact on the environment.

2.2 PTO restrictions

Here a set of PTO design criteria's will be analyzed to be considered in the design process affecting housing and electronics. Possible restrictions include:

- Mechanical: If the forces or speeds to be handled in the device jeopardize the structural integrity of the device as a whole or any of its components. For Sea-Titan project a maximum velocity of 3 m/s and a maximum force of 200kN are considered, as so, this restriction doesn't apply for Centipod technology, the WEC structure and components are designed to hold the necessary forces and velocities in a safe manner.
- Electrical: If the electrical components are not able to withstand the operational currents and voltages of the device in operation. For Sea-Titan project a maximum current of 300A is defined as well as a DC voltage of 1000V, the electrical components will be designed if need taking into account this consideration in a safe manner.
- Geometrical: The housing of the PTO is a key aspect when defining the design of the modular and crosscutting PTO, each technology developer has his own design which could affect the final shape of Sea-Titan PTO. In Seacap case this restriction doesn't apply, since the PTO housing is in the air gap between the deck and the float the PTO can be placed with plenty of guaranteed free space.

Figure 4. Seacap. PTO available space.

2.3 Improvement achieved with the new PTO solution

To be updated in month 33 based on a set of calculations carried for each of the 8 test scenarios defined

3. CENTIPOD

3.1 Technology description

Centipod WEC is comprised of:

- 3, 15m diameter point-absorber floats, each with their own PTO
- A common structure, which provides a reaction platform for the point absorbers

The mode of power extraction is vertical oscillation in the heave direction (typical point absorber)

Figure 5. Centipod. Scale model.

3.2 PTO restrictions

Here a set of PTO design criteria's will be analyzed to be considered in the design process affecting housing and electronics. Possible restrictions include:

- Mechanical: If the forces or speeds to be handled in the device jeopardize the structural integrity of the device as a whole or any of its components. For Sea-Titan project a maximum velocity of 3 m/s and a maximum force of 200kN are considered, as so, this restriction doesn't apply for Centipod technology, the WEC structure and components are designed to hold the necessary forces and velocities in a safe manner.
- Electrical: If the electrical components are not able to withstand the operational currents and voltages of the device in operation. For Sea-Titan project a maximum current of 300A is defined as well as a DC voltage of 1000V, the electrical components will be designed if need taking into account this consideration in a safe manner.
- Geometrical: The housing of the PTO is a key aspect when defining the design of the modular and crosscutting PTO, each technology developer has his own design which could affect the final shape of Sea-Titan PTO. In Centipod case diameters and relative lengths of the tubes are somewhat flexible at this stage of the design process but as a first approach a vertical tube approximately 24m in length with an upper and lower section:
    - Upper section outer diameter being 2.0m - suitable for a shaft and potentially translator clearance

- Lower section outer diameter being ~2.9m - suitable for housing the stator

Figure 6. Centipod. PTO Housing.

3.3 Improvement achieved with the new PTO solution

To be updated in month 33 based on a set of calculations carried for each of the 8 test scenarios defined

4. CORPOWER

4.1 Technology description

- Heaving buoy on the surface absorbing energy from the combined surge and heave motion of the waves. It has a pneumatic pre-tension module between the mooring line and the buoy. The WEC is connected to the seabed using a taut mooring line.
- Phase control by the WaveSpring technology makes the system inherently resonant over a broad range of wave periods, amplifying the motion and the power capture.
- The amplified linear motion is converted into rotation using a proprietary cascade gear box. Said gear box has a design principle similar to a planetary gear box, dividing a large load onto a multiple of small gears, providing high power density.

Figure 7. Corpower. 3D model.

4.2 PTO restrictions

Here a set of PTO design criteria's will be analyzed to be considered in the design process affecting housing and electronics. Possible restrictions include:

- Mechanical: If the forces or speeds to be handled in the device jeopardize the structural integrity of the device as a whole or any of its components. For Sea-Titan project a maximum velocity of 3 m/s and a maximum force of 200kN are considered, as so, this restriction doesn't apply for Centipod technology, the WEC structure and components are designed to hold the necessary forces and velocities in a safe manner.
- Electrical: If the electrical components are not able to withstand the operational currents and voltages of the device in operation. For Sea-Titan project a maximum current of 300A is defined as well as a DC voltage of 1000V, the electrical components will be designed if need taking into account this consideration in a safe manner.
- Geometrical: The housing of the PTO is a key aspect when defining the design of the modular and crosscutting PTO, each technology developer has his own design which could affect the final shape of Sea-Titan PTO. In Corpower case length and width must be taken into account since the PTO housing has a limitation of 8000mm in length and 1600mm in width, that implies that the PTO moving part needs to be half of the total available stroke, 4000mm, either that or a redesign of the PTO housing for Corpower.

Figure 8. Corpower. PTO housing.

4.3 Improvement achieved with the new PTO solution

To be updated in month 33 based on a set of calculations carried for each of the 8 test scenarios defined.