New Type of Linear Switched Reluctance Generator for Wave Energy Applications


CIEMAT

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WEDGE GLOBAL
The World of Wave Energy Converters

WORKING PRINCIPLE

OWC
PRESSURE DIFFERENTIAL
FLOATING STRUCTURE
OVERTOPING
OSCILLATING WAVE SURGE / IMPACT

LOCATION
ONSHORE
Limpet WaveGen (UK)

NEARSHORE
Oceanix Eneretch (AU)
CETO III REH (UK)
WaveStar WaveStar (DK)
Seareaser Seareaser (UK)
Waveplane Waveplane (DK)
Oyster Aquamarine (UK)

OFFSHORE
OE Buoy Ocean energy (IRL)
AWS AWS Ocean (UK)
Pelamis PWP (UK)
UNDIGEN Wedge Global (ES)
Wave Dragon Wave Dragon (DK)
Langley LWP (NO)
In a HPA the energy is produced from the relative displacement between the two bodies in the Power Take-Off. A Point Absorber has a small dimension compared to wave length and is able to harvest energy from any wave direction.
A Point Absorber is an oscillating system with a corresponding mechanical model, which can also be expressed in terms of the equivalent electric circuit. The circuit allows an easy determination of the required force at the PTO to extract the maximum energy from the wave.
The SEA TITAN Project

GOALS:
- Development of a new type of PTO based on SRM
  - Force Density x 2
  - IPCR x 2
  - FtWE up to 80%
  - Capex/kW down by 25%
  - LCoE down by 30%
- Modularity & Crosscuting up to 500 kN & 3m/s
- 3rd Generation of superconducting PTOs
- Business models based on “open hardware models”

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<tr>
<th>Participant Organization name</th>
<th>Type</th>
<th>Country</th>
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<td>1 (C) Wedge Global S.L.</td>
<td>WEC Developer</td>
<td>Spain</td>
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<td>2 CIEMAT</td>
<td>Public R&amp;D Center</td>
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<td>3 WavEC - Offshore Renewables</td>
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<td>R&amp;D Center</td>
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<td>11 Asociación Española de Normalización</td>
<td>Regulatory Body</td>
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The Principles of the Switched Reluctance Machines

The CYLINDRICAL SINGLE-SIDED SRM

THE CONCEPT OF THE MULTITRANSlator
RECTANGULAR SWITCHED RELUCTANCE MACHINE

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 764014
The Azimuthal SRM

The AZIMUTHAL SRM
(3-Phase Arrangement)

The AZIMUTHAL SRM
(Detail of One Phase)
Configurations for the Azimuthal SRM

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 764014
First Magnetic Calculations of the Azimuthal SRM

Coils Aspect Ratio has a great importance in the Force vs Position Curve

Machine Size Optimization

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3-D Magnetic Calculations for the Azimuthal SRM

Force calculations using 3D codes have also been performed. The force evolution is very sensitive to the wedge angle of the poles.
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 764014.
The Azimuthal SRM Prototype Overall Design

- ACTIVE SIDE COILS
- PASSIVE SIDE RINGS
- ROLLING GUIDES
- CONNECTING FLANGES BETWEEN RINGS

COMPLETE AMSRM PROTOTYPE MACHINE
The Azimuthal SRM Additional Calculations

DC Joule Losses + AC Losses + Iron Losses

MECHANICAL CALCULATIONS

Stresses on the Passive Side

Gap Misalignment

Stresses on the Active Side

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The PTO will be tested in a Back to Back configuration in which one of the machines acts as a generator and the other as a motor, both driven by an independent converter.
Towards a Superconducting Azimuthal SRM

A superconducting version of an AMSRM is theoretically attractive because:

- The machine has only one side with coils and this side can be stationary.
- Increasing the field from 2.1 T to only 2.3 T and the current density from 5 Amm\(^{-2}\) to 30 Amm\(^{-2}\) would mean increasing the force by a factor of 8.
- MgB\(_2\) can be an ideal candidate for the required levels of J & B, .......... BUT: AC losses can be inadmissible high and this requires special wire configuration and different operation of the machine (Single-Pulse and not Multi-Pulse).

**Force vs Current Density for different Field Values**

- Force decreases due to the worst coil aspect ratio

**Fundamental Period**

\[ \approx 0.067 \text{s} <> 15 \text{Hz} \]

**Switching Period**

\[ \approx 0.0067 \text{s} <> 150 \text{Hz} \rightarrow 1 \text{kHz} \]
• Heaving Point Absorbers are consolidated candidates for WECs
• Their capability to harvest energy is increased by hosting high force PTOs
• PTOs must produce a “vector” force (controllable in magnitude & phase)
• In April 2018 started the Sea Titan Project to develop a new concept of PTO based on a linear Switched Reluctance Machine.
• This PTO is based on an Azimuthal configuration that saves iron and has a better adaptation to the WEC geometry.
• The main deliverable of the Project is a 70 kN, 3ms⁻¹ prototype to be tested horizontally at CIEMAT premises.
• This prototype has been magnetically, mechanically and thermally calculated and its design is practically finished.
• Additionally, Sea Titan considers the conceptual design of a superconducting version based on Mg B₂.

THANK YOU VERY MUCH !!!!!