Prototype and Codesign of Nascent Flexible Wave Energy Converter Concepts

Seedling Showcase 11 August 2021

Blake Boren

Domain 1 – The Mainstream: Monolithic Rigid Bodies With Singular Power Take-Off

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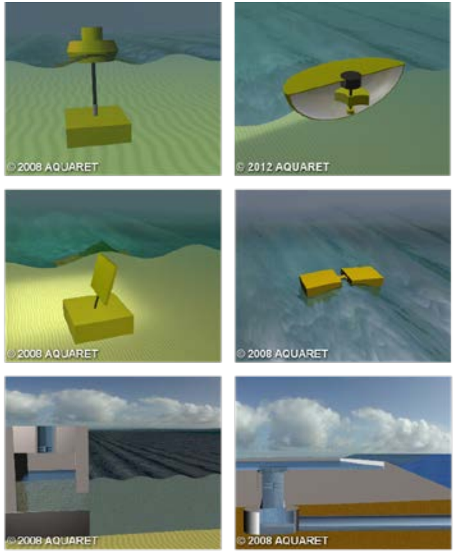
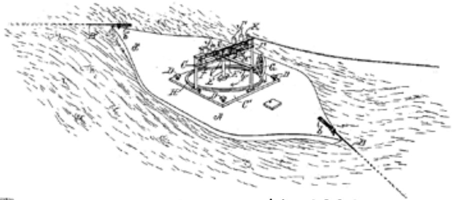
Distributed Embedded Energy Converter Technologies



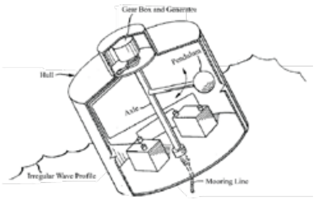
Prevailing mainstream ocean wave energy converter archetypes.
Figures sourced from https://aquaret.com/

Domain 1 Hallmarks

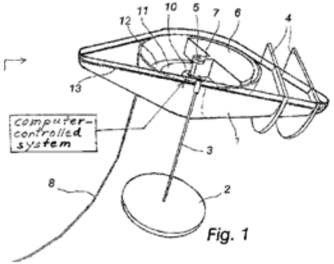
- Relatively large, monolithic, rigid bodies.
- Singular means of power take-off
  (e.g., relative motion between rigid bodies).
- Solo, prime-mover mechanisms
  (e.g., rotary generator, hydraulic piston).
- Gears, bearings, hydraulic pressures, accumulators, fluids, seals.



Patented in **1894**
(Joseph Singer)
Pat. No. US524490A



Patented in **1966**
(Thiokol Chemical Corp.)
Pat. No. US3231749A



Patented in **2014**
(Wello Oy)
Pat. No. US8915077

Long Histories of Interest and Investment

- Existed for decades.
- Significant funds put forth for research & development.

Domain 2 – Paradigm Shift: Distributed Embedded Energy Converter Technologies

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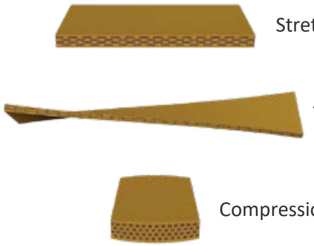
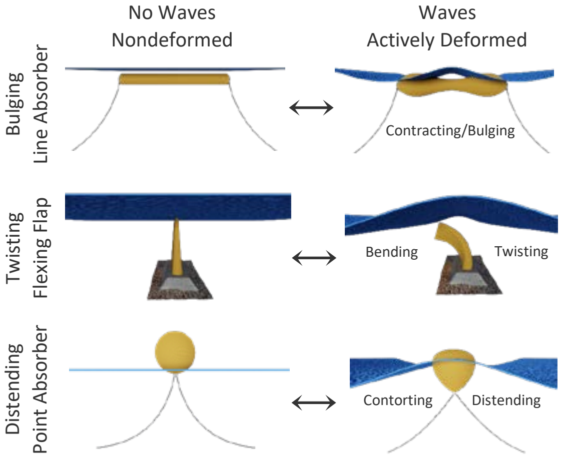
Distributed Embedded Energy Converter Technologies

A sample volume illustrating an overview of the subcomponents of a stretched/deformed DECC-Tec.
Illustration by Blake Boren, NREL



Illustrative sample volume being dynamically deformed; principal manners of operation.
Illustration by Blake Boren, NREL



FlexWEC archetypes showcase the nondeformed and dynamically deformed states of DEEC-Tec-based flexWEC structures.
Illustration by Blake Boren, NREL

DEEC-Tec structures are used to create whole flexible wave energy converters (flexWECs).

FlexWEC, being a portmanteau word, means:

(1) The compliant nature of DEEC-Tec structures.

(2) The overall structure's purpose to harvest and convert ocean wave energy.

Example from industry:
SBM Offshore's S3 device
https://bit.ly/3idzliq

Domain 2 Hallmarks

- Energy conversion directly *in situ* throughout distributed embedded energy converter technologies (DEEC-Tec) structures.
- Inherent broad-banded ocean wave energy conversion; near continuous degrees of freedom.
- No focus or concentration of forces into centralized, prime movers.
- Inherent redundancy.

Domain 1 Area vs. Domain 2 Area – Motivation for Seedlings

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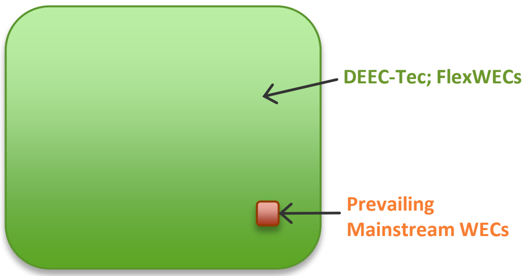
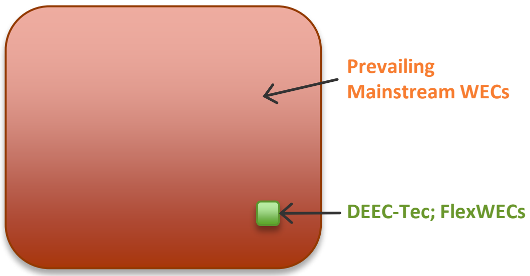


Areas of Research and Development (R&D) Opportunity



Areas of R&D Funding

Motivation

An opportunity for cursory investigations into some areas of applied DEEC-Tec.

Prototyping Seedling Investigations

- Material types
- Fabrication techniques
- Evaluation methods
- Laboratory structures
- Computer-aided design (CAD) modeling
- Data acquisition requirements
- Instrumentation needs.

Codesign Seedling Investigations

- Fluid-structure interaction
- Modeling elastic and hyperelastic materials
- Topologies (flexWEC geometries and forms)
- Morphologies (flexWEC compliant characteristics)
- Applied, high-performance-computing modeling methods.

And Outreach

(Diversity, equity, and inclusion via interns and postdocs)

Investigations

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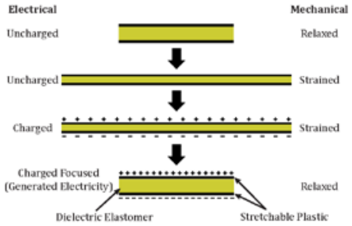
Distributed Embedded Energy Converter Technologies

Prototyping

R&D for Fabrication and Evaluation of DEECs

- Identify possible transducers for use as DEECs.
- Design and CAD modeling.
- Develop requirements for instrumentation and laboratory requirements.

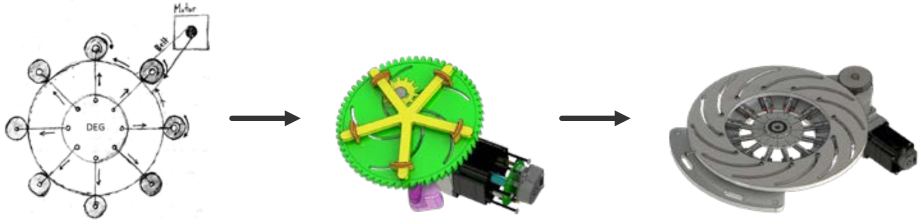


Principals of Operation of a DEG.
Illustration by Blake Boren, NREL

Notable Outcomes

- Developed design capable of both fabrication and evaluation of dielectric elastomer generators (DEGs).
- Designed and acquired laboratory space for prototyping.
- Cursory evaluation of elastomers; displacement models.

Design developments: DEG fabrication and an evaluation rig



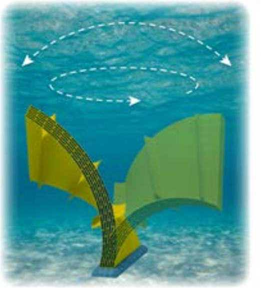
Codesign

An Investigation for Codesign and Multiphysics

- Computational demands aiming to truly enable codesign of flexWEC technologies.
- Avenues for numerical modeling.
- Numerical modeled wave tank.
- Deformable geometries.

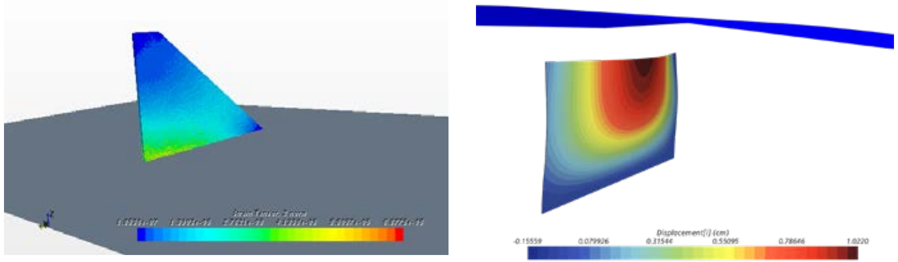
Notable Outcomes

- Isolated conducive methods for numerical modeling and enabling codesign of flexWECs via Siemens Star-CCM+; Eulerian multiphase, volume of fluid, hyperelastic materials.
- Generated report showcasing success.



The investigation centered on the bottom-mounted, surging flexWEC archetype.
Illustration by Josh Bauer, NREL

The investigation centered on two geometries.



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Thank You

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NREL/PR-5700-80625

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by Water Power Technologies Office, U.S. Department of Energy Office of Energy Efficiency Renewable Energy. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

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