Developing a Double Loop Hypertwist Generator (DLHG) for Wave Energy Applications

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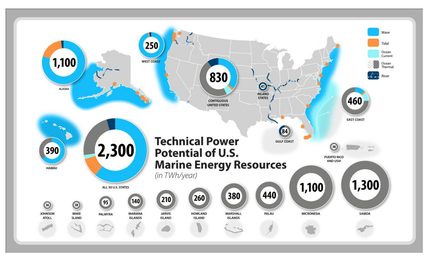
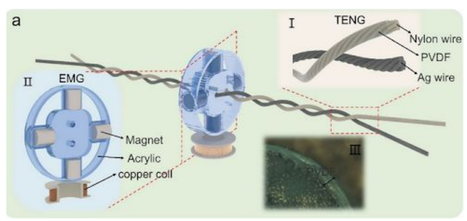
The DLHG prototype is able to transform low-frequency wave motion into high-speed rotary motion producing up to 7.6 Watts of electrical power.

Relevance

- Wave energy is an abundant resource [1], but the low frequency wave energy can only be captured with reliable, efficient power take-off systems.
- Power take-off design is a key activity for many wave-energy developers, who have used mechanical gearboxes, magnetic gearboxes, hydraulics, and direct-drive schemes.
- Outside of wave energy research, researchers investigated hypertwist powered rotors for nanogenerators.



[1]

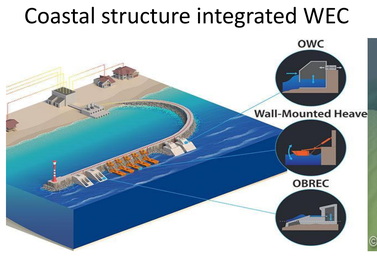


[2]

Applications

- Proposed PTO can be adapted to numerous WEC topologies as shown below.

Coastal structure integrated WEC



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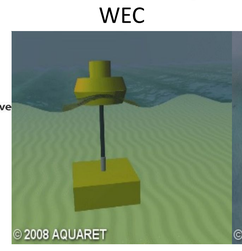
Point Absorbing WEC



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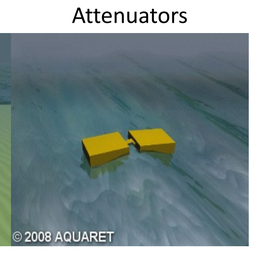
Attenuators



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Results

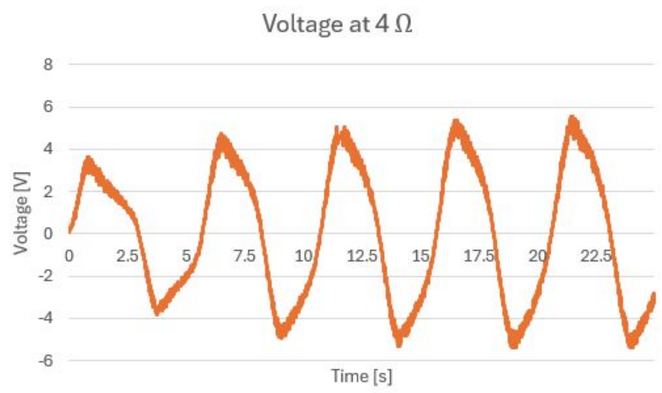


Figure 1: Unrectified voltage output in Volt over time in Second at a constant resistance of 4 Ω where the voltage follows a rampant scale as an alternating DC current until it moves towards a steady state

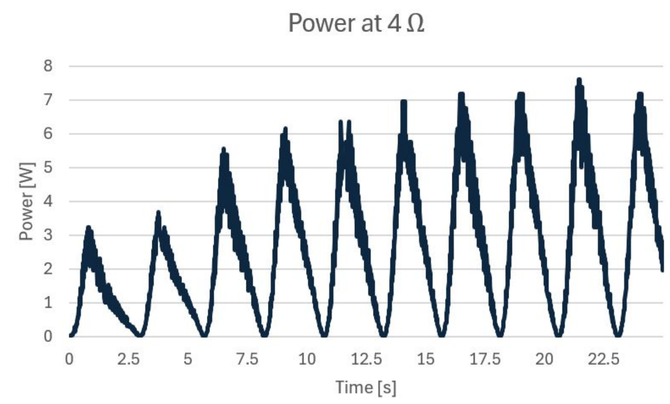


Figure 2: Power output as a function of time, with a constant resistance of 4 Ω

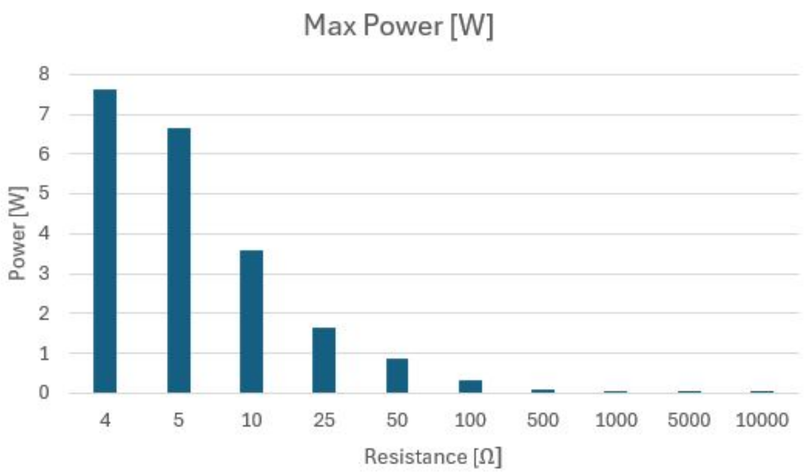


Figure 3: Maximum power output in watts over different resistances

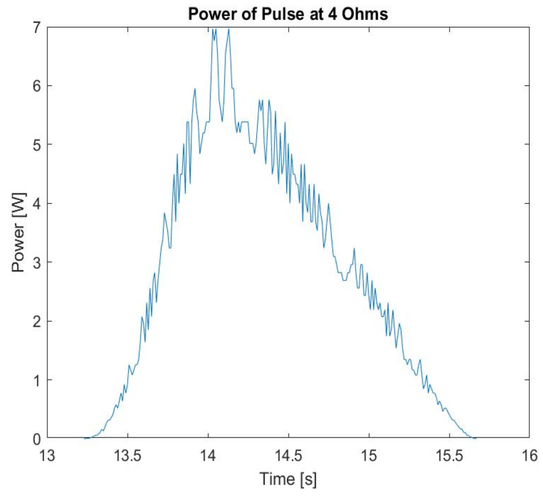
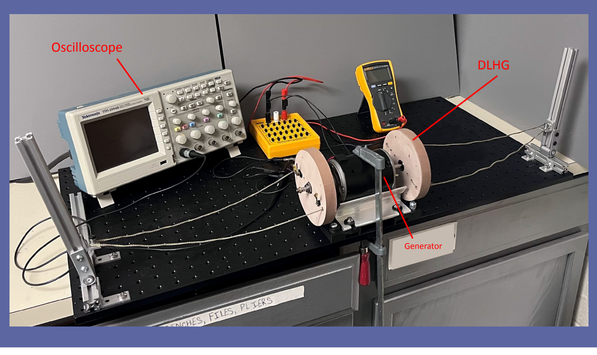


Figure 4: Power in watt for a single unwind cycle, integrated to determine energy in joules per pulse

Benchtop Testing Setup

- DLHG: in the front with two strings each attached to a wheel, which are connected to a motor with a through shaft
- Motor connected to resistance monitor and oscilloscope measuring voltage



Discussion

The double-loop hypertwist generator prototype has been successful in transforming low-velocity cyclical tension on the loops into electricity. While the preliminary results reflect a generator that has not been optimized, the electrical power produced (peak and average) is already in the watt range, which matches some powering the blue economy (PBE) applications. The four phases of the hypertwist operation (unwinding, winding, reversed unwinding, reversed winding) are sustained across a range of resistive loads and the hypertwist operation can be achieved across a range of input frequencies, which will be critical when the PTO is integrated with a wave energy converter.

Upcoming Developments

- Automate the driving force via a pneumatic system for force analysis and repeatable motion
- Generator optimization for higher power output
- Integration with a WEC
- Wave Tank Testing

References

[1] L. Kilcher, M. Fogarty, and M. Lawson, "Marine Energy in the United States: An Overview of Opportunities," 2021. Available: https://www.nrel.gov/docs/fy21osti/78773.pdf
[2] X. Dan *et al.*, "Whirligig-Inspired Hybrid Nanogenerator for Multi-strategy Energy Harvesting," vol. 5, no. 1, pp. 362–376, Nov. 2022, doi: https://doi.org/10.1007/s42765-022-00230-y.
[3] "Coastal Structure Integrated Wave Energy Converters," *Nrel.gov*, 2024. https://www.nrel.gov/water/coastal-structure-integrated-wave-energy-converters.html (accessed Aug. 02, 2024).
[4] "Wave devices : EMEC: European Marine Energy Centre." https://www.emec.org.uk/marine-energy/wave-devices/

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