Final Report of Project Funded by MIT Portugal Partnership (MPP2030)
Research Seed Funding Program

Project Title:
Ocean Wave Energy Harvesting by an Innovative Proof-Mass Stand-Alone Buoy Converter

Research Area(s):
Climate Science & Climate Change (area 1), Earth Systems: Oceans to Near Space (area 2)

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Summary

An innovative ocean marine energy converter was developed, designed to harvest the wave induced kinetic energy of oceanographic buoys, underwater vehicles, and other floating structures. The motion of proof-mass levitating magnets oscillating inside sealed containers is converted directly into electricity via an electromagnetic Power Take-Off mechanism. Actively controlled and passive PTO mechanisms were studied. The marine energy converter developed under this project was shown to be a low-cost and robust way to harvest wave induced energy in broad-banded seastates. A sample layout of an array of levitating magnets mounted on a buoy is illustrated in Figure 1.

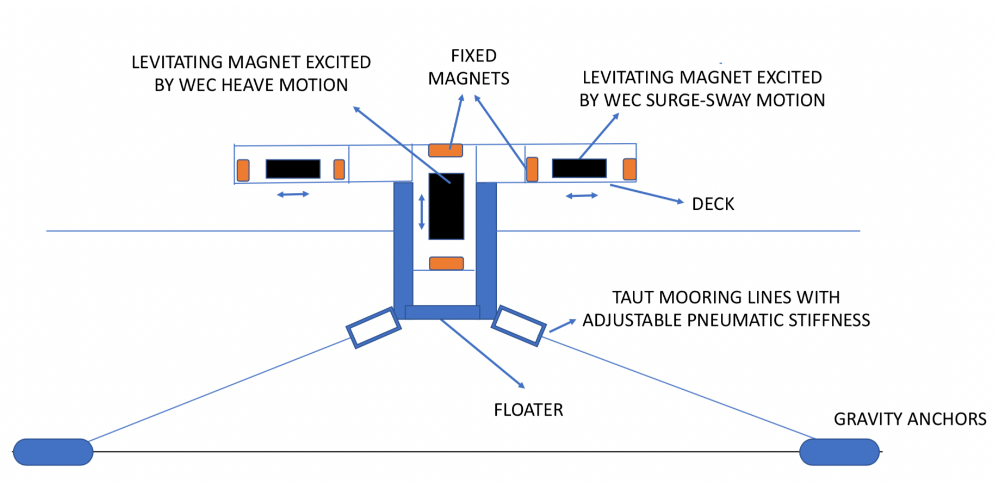


Figure 1: Adjustable Stiffness Taut Mooring Line Proof-Mass Wave Energy Converter

1. Harvester Design

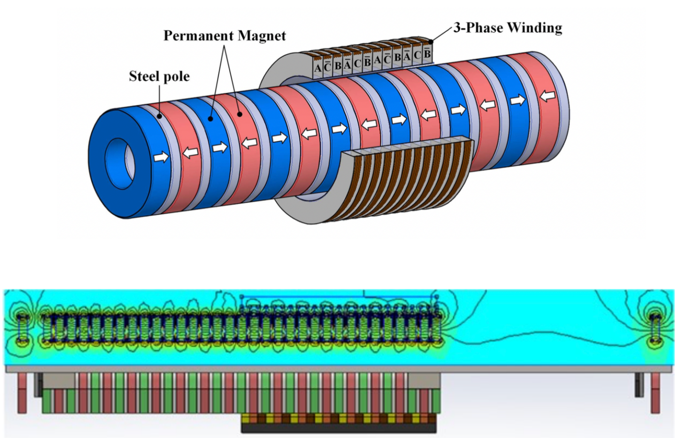


Figure 2: Magnet and Coil Geometry – FEM Solution of Magnetic Field

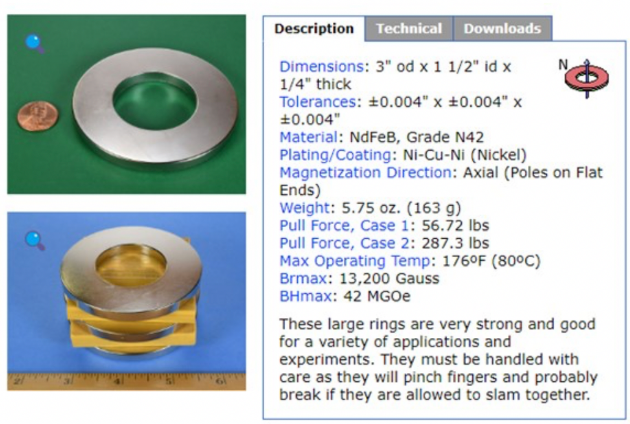
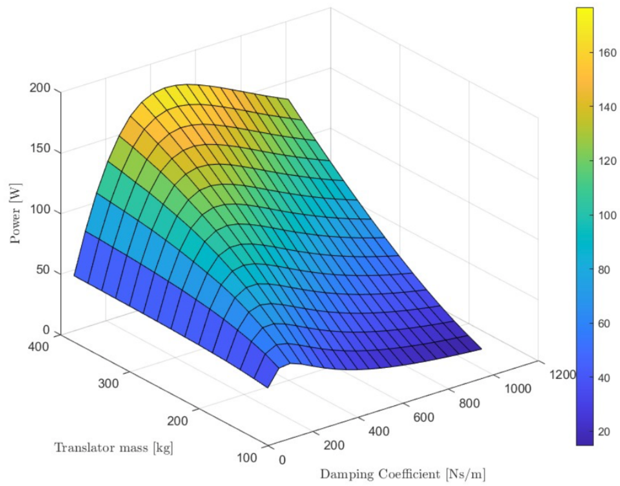


Figure 2-6: Ring magnet spec sheet from kjmagnetics.com



$$Pmax = B \boldsymbol{\sigma}_v^2 \sim 70\ W/m^3$$

Figure 3: Harvested Power vs. Translator Mass, Electromagnetic Damping B and Standard Deviation of Proof-Mass Velocity Under Broadband Operation

2. Conclusions

A proof-mass electromagnetic marine energy converter was developed. Its principal attributes are its low cost, ease of manufacture using off-the-shelf components and the ease of its distributed deployment in various sizes inside marine buoys and vessels for the generation of electricity. Passive and optimally controlled versions of the harvester were studied. While more energy is harvested by an optimally controlled harvester, the passively operated harvester is preferred in a broad-banded ocean environment where the operation of the optimal control sensors and circuitry may be challenging.

For the passive harvester, there is no need to tune the natural frequency of the oscillating proof mass to the oscillation frequency of the supporting floater. It was found that under passive operation, maximum power is harvested for a high value of the electromagnetic damping B and a large velocity of the proof mass oscillation between the ends of the container. The latter condition is achieved with a larger translator mass which is accommodated by the buoyancy of the support floating structure.

3. References

Zhang, F. (2021). Optimal Control of a Novel Wave Energy Converter. Master of Engineering Thesis. Department of Mechanical Engineering, MIT.

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Stone, L. (2023). Oscillating Energy Harvester for UUV Applications. Master’s of Science Thesis. Department of Mechanical Engineering, MIT.