Wave Energy Converter

Aqua-Watt Technologies

Dear consultants, At Aqua-Watt Technologies, we aim to harness the immense power of ocean waves to generate clean electricity. Our primary device is planned to be a "point absorber", which is essentially a large buoy that heaves up and down with the motion of the waves. This motion drives a generator inside the buoy, converting the kinetic energy of the waves into electrical power.

The concept is simple, but the performance is highly dependent on the dynamic interaction between the buoy and the waves. To maximize the energy we capture, we need to "tune" the buoy's response to the frequency of the incoming waves. This involves carefully choosing the buoy's mass and shape, and controlling the damping force from the generator.

We need your help to develop a mathematical model that describes the dynamics of a point absorber to allow us to optimize the design and the control strategy for different sea conditions. We are interested in the following questions:

- What is the natural frequency of oscillation for the buoy? How does this compare to typical ocean wave frequencies? How does the amplitude of the buoy's motion change with the frequency of the incoming waves? Can you identify the resonant frequency where the motion is maximized?
- The power absorbed is related to the damping force from the generator. How should this damping be controlled to maximize the extracted power? This may not be the same as maximizing the motion itself.
- What is the "capture width" of the device? How does it vary with wave frequency and the power take-off (PTO) damping strategy?
- Real ocean waves are irregular. Could you adapt a model assuming simple sinusoidal waves, to represent a more realistic sea state?

You could extend your model to consider more degrees of freedom (surge, pitch), non-linear forces, frequency-dependent parameters and more advanced control strategies.

To begin, we see that others have modelled the vertical (heave) motion of a point-absorber buoy in response to the ocean waves as a forced, damped harmonic oscillator (see Appendix C in [1]). The forces acting on the buoy include: its own weight and the restoring force of buoyancy (which acts like a spring), a driving force from the incoming waves (the excitation force), hydrodynamic damping forces (including radiation damping — energy lost by the buoy creating its own waves) and the power take-off force from the internal generator, which acts as a controllable damping mechanism (see [3] [2] for more details).

We look forward to your analysis.

References

[1] Job Dronkers. *Wave energy converters*.
URL: https://www.coastalwiki.org/wiki/Wave_energy_converters.

[2] Houssein Yassin et al. "Optimal Control of Nonlinear, Nonautonomous, Energy Harvesting Systems Applied to Point Absorber Wave Energy Converters". In: *Journal of Marine Science and Engineering* 12 (2024), p. 2078. DOI: https://doi.org/10.3390/jmse12112078.

[3] Shangyan Zou et al. "Optimal control of wave energy converters". In: *Renewable Energy* 103 (2017), pp. 217–225. DOI: https://doi.org/10.1016/j.renene.2016.11.036.