ASX ANNOUNCEMENT

17 June 2021

Improving CETO Performance through Advanced Control:
Update on Control Achievements

Carnegie Clean Energy (ASX: CCE) is pleased to provide an update on the substantial strides made on Advanced Control through the CETO Digital Development Pathway over recent months. Advanced Control has been one of the core innovation streams pursued by the team over the last 18+ months with multiple advanced controllers being developed internally and with partners. These controllers instruct the Power Take-Offs (PTOs) to set the tension in CETO's mooring lines which are resisting the wave forces imposed on the buoy. When set optimally, CETO can extract considerably more energy from each wave.

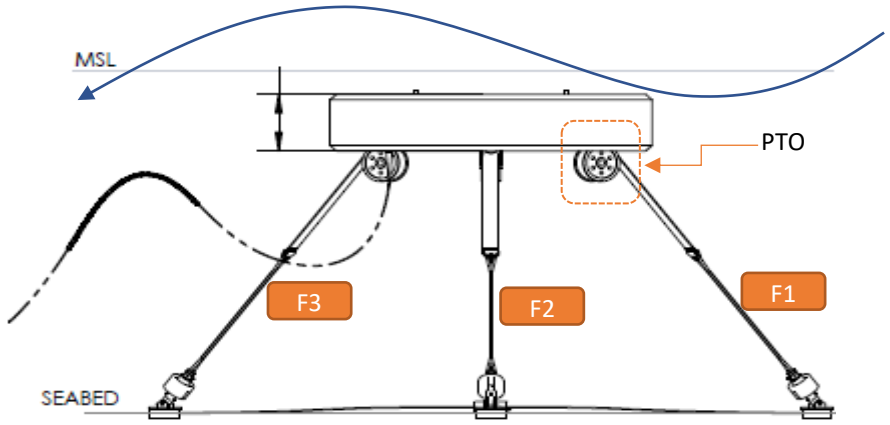

Figure 1- Side view of CETO with tensile mooring forces identified by labels F1-3

The work is delivering significant improvements in CETO performance with recent analysis showing the suite of advanced controllers currently achieving up to 27% more energy than the baseline CETO controller.

The broader goal goes beyond just energy production and that is to reduce the cost of energy overall to make CETO more competitive in a wider array of markets. While improvements in energy performance translate directly to an equivalent reduction in the cost of energy, these controllers can additionally reduce CAPEX by capping forces and motions that drive the need for additional strength or travel length. Accordingly, there are promising controllers in development which while not delivering the highest energy performance improvements, are delivering high reductions in the cost of energy.

Summary of work completed

The control algorithm has the critical function of tuning CETO to each incoming wave, to maximise extracted power, as well as minimise extreme responses. Over the past year, Carnegie has worked both internally and with external partners to investigate a range of advanced controllers for CETO which have the potential to outperform the historical Spring-Damper controller. Leveraging on existing and new partnerships has allowed Carnegie to increase the number of investigated controllers, access world class expertise, and widen the scope of the investigation, with both physics-based and AI-based controllers being studied.

- University of Adelaide and Carnegie are working on an efficiency aware Model Predictive Controller (MPC). The MPC is a physics-based controller which relies on wave prediction to compute the optimum Power Take-Off response.
- Hewlett Packard Enterprise (HPE) are working with Carnegie on Reinforcement-Learning-based controllers. Reinforcement-Learning is a type of Artificial Intelligence where the system under consideration teaches itself how to operate optimally. Because it has systematic machine-driven algorithms to explore the control space, it has the potential to outperform human-programmed controllers, as has been demonstrated in areas such as autonomous car driving.
- French company IFPEN and Carnegie worked together on a spectral controller. The spectral controller allows estimation of the theoretical maximum power output of CETO models in the simulation space. It serves as a useful benchmark for other controllers.
- Internally, Carnegie has been working on an advanced version of the spring damper controller, which directly aims at reducing the cost of energy by minimising the cost of the PTO. In addition, the team has also been focusing on introducing elements of Artificial Intelligence into the MPC controller.

During these studies, the various controllers were coupled to hydrodynamic numerical models of CETO to estimate their performance, the results of which are summarised below. As the figure demonstrates, the advanced controllers are demonstrating significant performance improvements compared to the baseline spring damper controller.

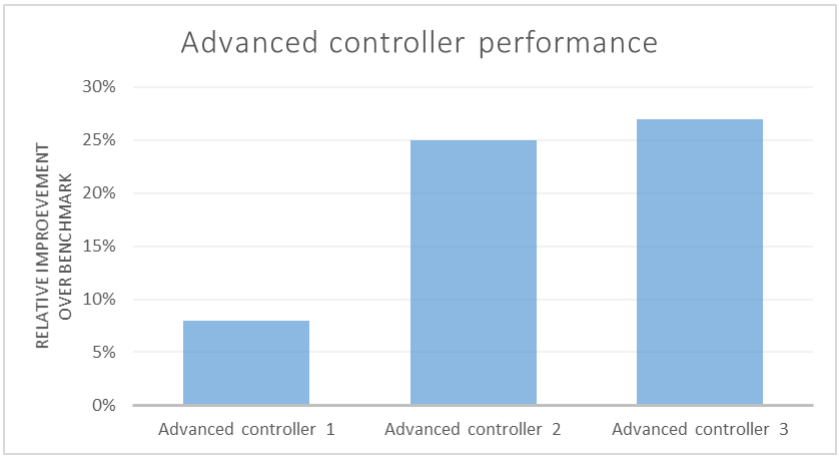

Figure 2: Advanced controller performance improvement compared to benchmark spring damper controller

Upcoming Controller Activities

Carnegie's reinforcement learning control partnership with HPE will be recognised at HPE Discover, the global business conference showcasing HPE's vision for the future. HPE Discover 2021: The Edge-To-Cloud Conference, normally held in Las Vegas, is being held virtually on June 22-24, 2021. Carnegie and HPE's work will be highlighted in multiple sessions including:

- Carnegie's CEO Jonathan Fiévez will be a keynote speaker in *Discover Day 3 Keynote - The Radical Rethink: Unconventional Ways to Unlock the Power of Data*
- At breakout sessions - *Hewlett Packard Labs and Carnegie Clean Energy Revolutionize Wave Energy With Reinforcement Learning*

With the conference registrations exceeding 55,000 business and government participants from around the world, this significant opportunity will showcase Carnegie's CETO technology and the innovative reinforcement learning control being developed collaboratively by Carnegie and HPE.

Over the next few months, the team will continue to advance the most promising controllers in preparation for a physical tank testing campaign at a major international wave tank towards the end of the year. The tank testing will include the operation of a CETO model using the best advanced controller(s) and will validate the extensive simulations and modelling work done and ultimately verify the performance improvements delivered by advanced control.

This tank testing validation combined with the outcomes of the hydrodynamics and power take-off innovation streams expected in the next 6-9 months will support verification and validation of the outcomes of Carnegie's Digital Development Pathway – ultimately the delivery of a CETO design with step change improvements in both performance and cost that support the commercial pathway of the technology.

This announcement has been authorised by the Chairman and Company Secretary.

For more information

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