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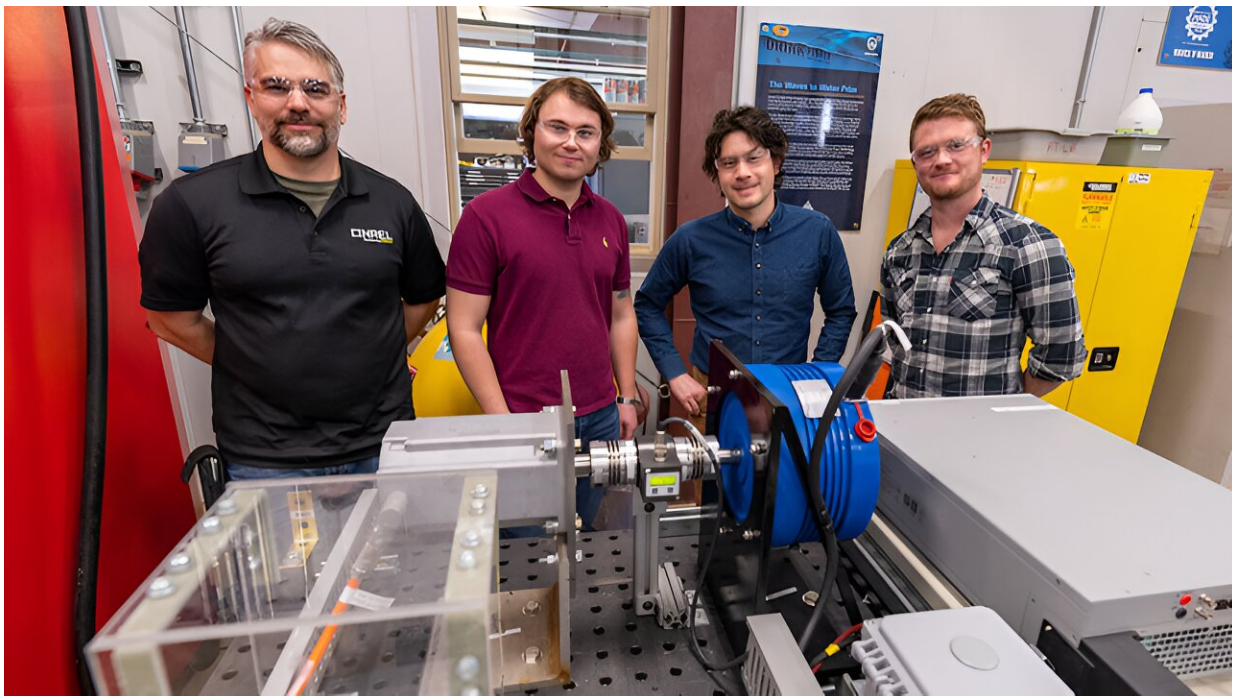
How gray boxes and a jellyfish could help advance wave energy

December 14 2023, by Caitlin McDermott-Murphy



Mark Murphy, Casey Nichols, Nathan Tom, and Ben McGilton recently built a new testing platform that blends virtual simulation and physical hardware to help wave energy technology developers quickly and inexpensively hone their designs. Credit: Werner Slocum, NREL

To an outsider, the gray stack of metal boxes piled on the gray concrete floor might look unimpressive. Machinery meant for storage, maybe. Leftovers from an experiment completed long ago.

"It's unassuming," said Nathan Tom, a mechanical engineer at the National Renewable Energy Laboratory (NREL), "and sure doesn't look much like a wave energy converter."

But it is—sort of.

Those boxes hide a unique testing platform that can merge virtual and physical worlds. Imagine a car-racing video game that connects to an actual car engine. That is what Tom and his colleagues built—except their platform is designed for up-and-coming wave energy technologies.

Waves carry enough energy to meet about 34% of the United States' electricity needs. We cannot capture all that power, but this largely untapped resource could still pair up with other renewable energy sources to power offshore activities—like seafood farming, carbon capture, or ocean research—and help the country decarbonize its power grid. But before these technologies can join the fight against climate change, technology developers must design devices that can generate hearty amounts of energy while surviving a ferocious, salty ocean—all without draining a developer's bank.

And to accomplish all that quickly enough to get wave energy onto the grid, tech developers must hurdle a testing chasm—one that this testing platform could help bridge.

Or, as Tom put it: "With our setup, we can straddle two worlds."

How to straddle two worlds

On one side of that testing chasm is a virtual, numerical world that mirrors the real one. In this virtual space, technology designers can explore different generators, play with shape and scale, and even subject their tech to simulated waves.

"But then you try to hook your design up to something real, and you realize that some of the assumptions you made are probably incorrect," Tom said.

The real world, the other side of the testing chasm, is often messier than any virtual replica.

But tossing untested prototypes into reality—the sea—is not necessarily a better option. Ocean trials are risky: If a device does not operate as smoothly as the data said it should or if a critical component breaks out in the depths, developers could waste a whole lot of time and money extracting their defunct design.

But with the team's new testing platform, developers have a third option, one that blends the playful freedom of theoretical models with the stark reality of a physical generator or subsystem. With that, Tom said, "you could be more confident in your device and its components and at a fraction of the cost of going out into the ocean."

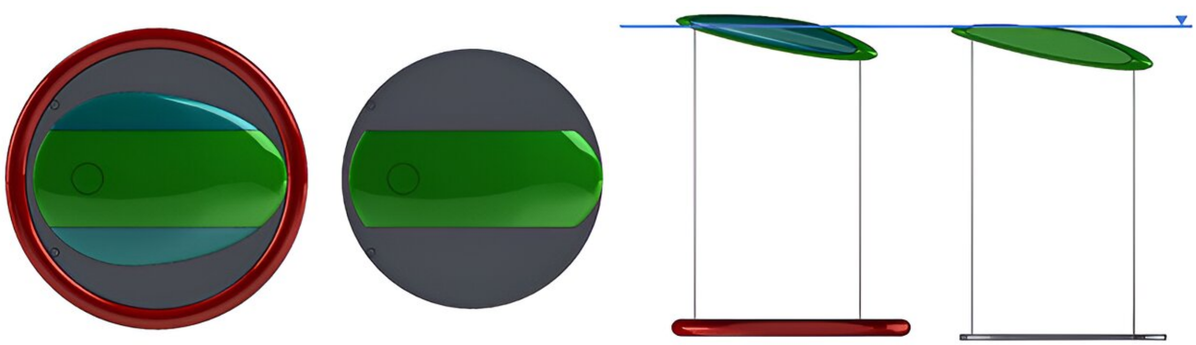
And Tom would know: He has already taken the platform for a spin.

How an extra data loop helps evaluate a novel wave energy design

Tom not only helped build the new testing setup; he already used it to evaluate a novel wave energy device under development at NREL. The design, called a variable-geometry wave energy converter, can inflate and deflate to avoid potentially destructive extreme waves. This and other variable-geometry designs could help wave energy technologies generate more energy, survive longer, and cost less.

But before developers pivot to such a new design, Tom set out to determine whether variable-geometry would be worth the investment. "We have to show benefits," Tom said, "and when I say benefits, I'm not talking a 5% bump in efficiency. We have to show closer to 25% at least, or else it might not be worth investing in the complex variable-geometry concept."

To do that exploration, Tom added an extra layer of complexity to the team's testing platform. Now, they can feed live data from physical hardware, like a generator, back into their virtual model, the Wave Energy Converter SIMulator (WEC-Sim). With that extra data loop, WEC-Sim, which is an open-source code developed by NREL and Sandia National Laboratories, can collect even more accurate results. Take that car-racing video game: It is as if the game learned to better imitate a car driving up a steep hill after digesting data from how an actual car engine behaves when subjected to a simulated hill.



A jellyfish-like device, seen here from above (two left images) and from the side (two right images), could be a more efficient and cost-effective way to harness wave energy. The device geometry can morph to adapt to changing sea conditions, as seen here. Credit: Graphics by Nathan Tom, NREL

"We're feeding what we're measuring in real life back into the model, so if your motor stopped working, the simulation should respond in real time," Tom said. "With that, we can get a precise look at exactly how the hardware responds to the simulation and how to improve the design to produce more energy."

Wave tanks, machine learning, and the jellyfish

Wave energy developers can use other tools, like NREL's new wave tank or motion platform, to bridge the virtual-physical gap. And while wave tanks can provide valuable data on how a device responds to actual water, most can only fit scaled-down versions of a prototype, which means developers must still make assumptions about how those data translate to a full-scale device. Although the motion platform can hold full-scale prototypes, it cannot feed data back into theoretical models that learn, adapt, and spit out more accurate feedback.

The team's new testing platform can do both. Developers can simulate a scaled-up version of their design to evaluate larger-scale or even full-scale generators used in smaller wave energy devices—like those designed to power offshore seafood farms, ocean observation sensors, or ocean water desalination.

"It's one of the first times in the world that someone has created this kind of WEC-Sim-in-the-loop setup," said Ben McGilton, a research engineer at NREL, referring to the loop created by plugging physical hardware, like a generator, directly into a virtual world.

McGilton brought electricity to the project: As part of the electrical team, he used the platform's data to figure out how to build a more efficient version of the variable-geometry wave energy device—which he says resembles a jellyfish.

The new testing platform pinpointed a few potential flaws in the jellyfish design, which is exactly the point. Now, Tom can hone the design before it undergoes further testing.

But the platform can do more than test a jellyfish-like device. An NREL team working on a wave-powered desalination device plans to assess how their generator reacts if their device charges a battery. And industry partners could visit NREL to evaluate their generators through programs like the Testing Expertise and Access for Marine Energy Research program (known as TEAMER).

In time, Tom hopes to pair the platform with machine learning algorithms. With machine learning, the platform could help identify optimal ways to control how much energy a generator produces as waves swell from small to big to extreme. All this precise data and control could accelerate technology development and help get wave energy technologies out in the water.

"With this setup," Tom said, "we can give researchers and developers answers that are less "Let's explore this' and more "This is what you're going to come across, and you should address it now.'"

Provided by National Renewable Energy Laboratory

Citation: How gray boxes and a jellyfish could help advance wave energy (2023, December 14) retrieved 29 April 2024 from
https://techxplore.com/news/2023-12-gray-jellyfish-advance-energy.html