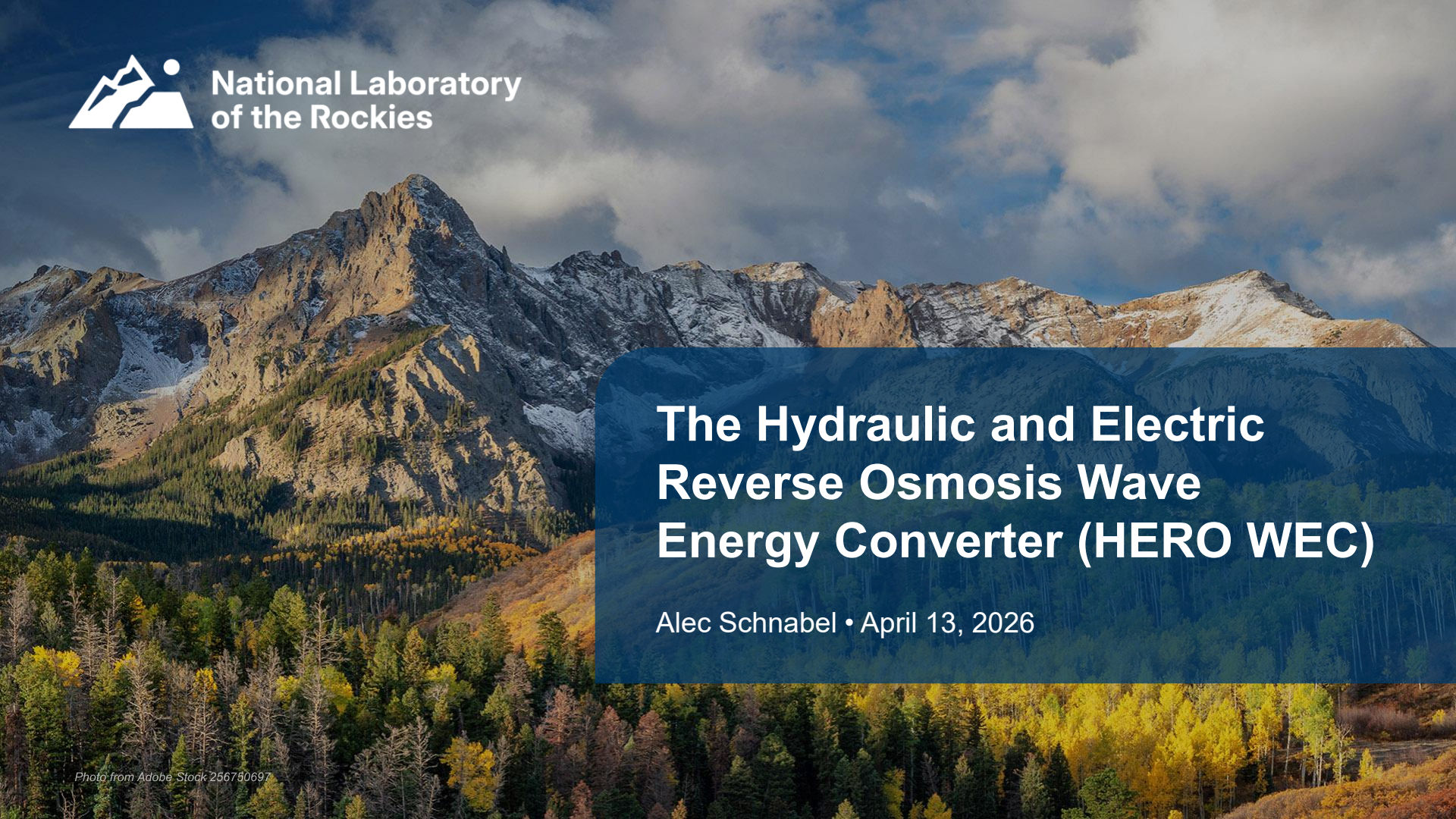

National Laboratory of the Rockies

The Hydraulic and Electric Reverse Osmosis Wave Energy Converter (HERO WEC)

Alec Schnabel • April 13, 2026

Photo from Adobe Stock 256750697

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Introduction

Introduction

Hydraulic and Electric Reverse Osmosis Wave Energy Converter

- The HERO WEC is a desalination device to create fresh water from near-shore ocean waves.
- It is designed for quick deployment in disaster scenarios when water supply is compromised.

Photo from John McCord, Coastal Studies Institute

Introduction

Origin of HERO WEC

- The HERO WEC originally served to de-risk H2O's Waves to Water Prize.
- Subsequent development and deployments give National Laboratory of the Rockies (NLR) researchers a test bed for new ideas.
- Open-source design allows industry to use lessons learned.

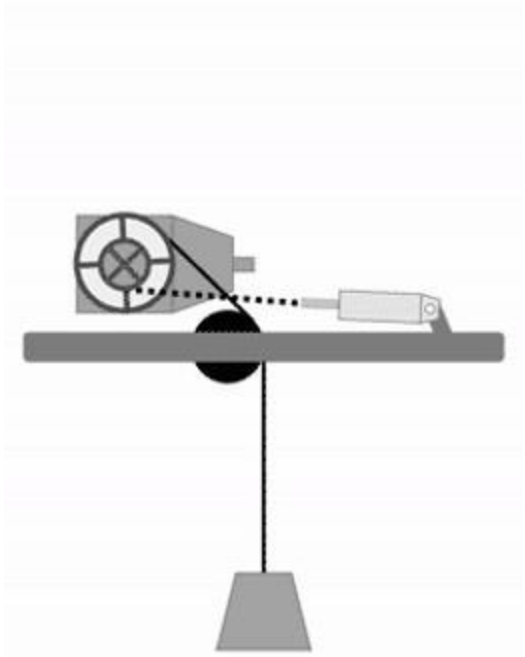
Photo from John McCord, Coastal Studies Institute

Design

Design: Mechanical

How does it work?

- The Point-absorber WEC
  - Heave motion pulls on mooring line, creating rotational motion through a gearbox
  - Rotational motion spins either a generator or a hydraulic pump
  - Winch winds line back with pressure from air spring.



Design: Mechanical

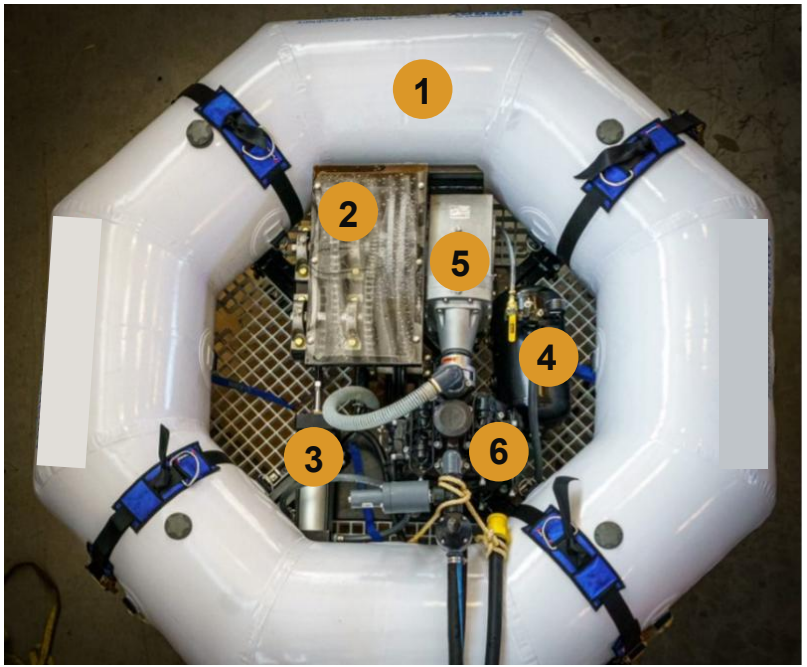
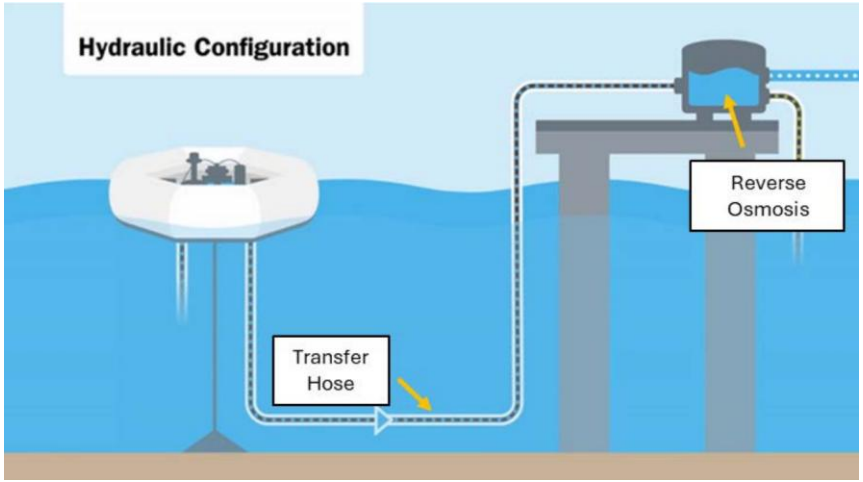


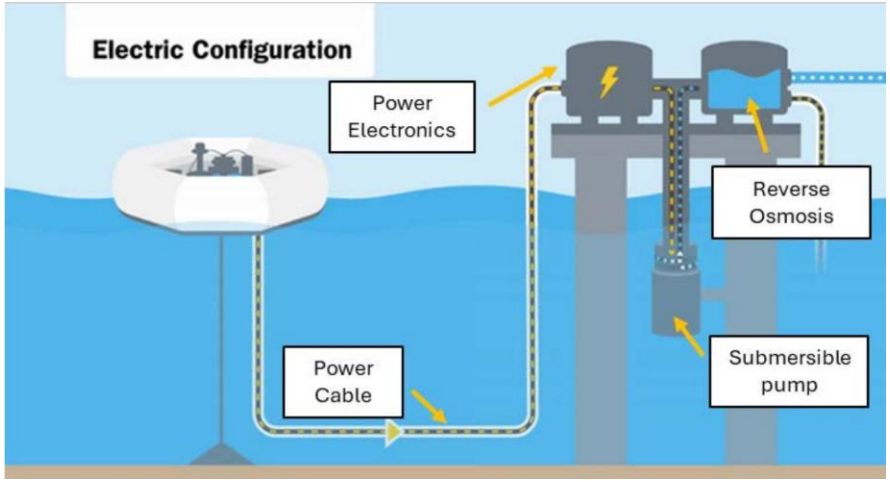
Photo by Andrew Simms, National Laboratory of the Rockies (NLR)

Mechanical Components

1. Octagonal inflatable float
2. Winch (underneath guard)
3. Air spring
4. Air tank
5. Gearbox
6. Pump

Design: Mechanical





Design: Mechanical

Hydraulic System

- The rotary, six-diaphragm pump was originally intended for agricultural applications.
- Two pressure relief valves keep the system from over-pressurization.
- The pump is connected to a hose running across the seabed to provide the necessary pressure to the reverse osmosis system on shore.

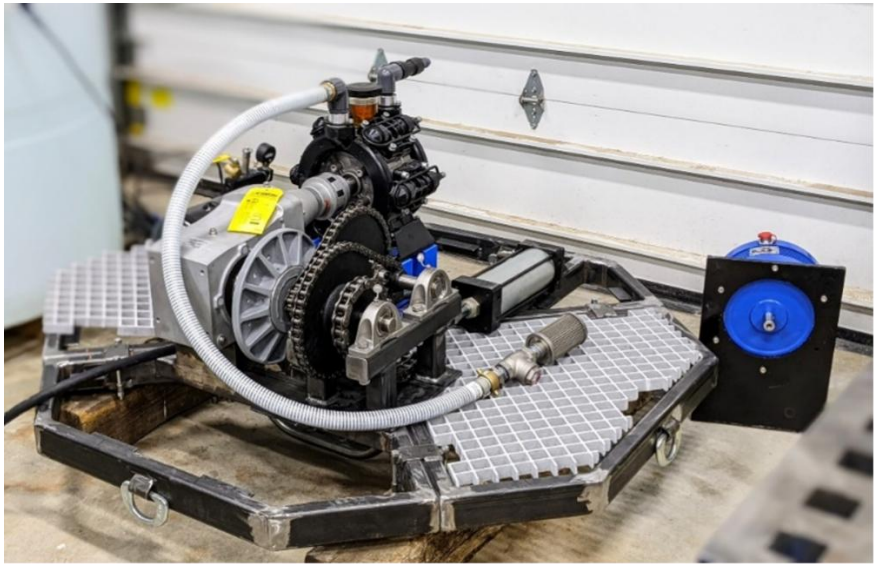


Photo by Andrew Simms, NLR

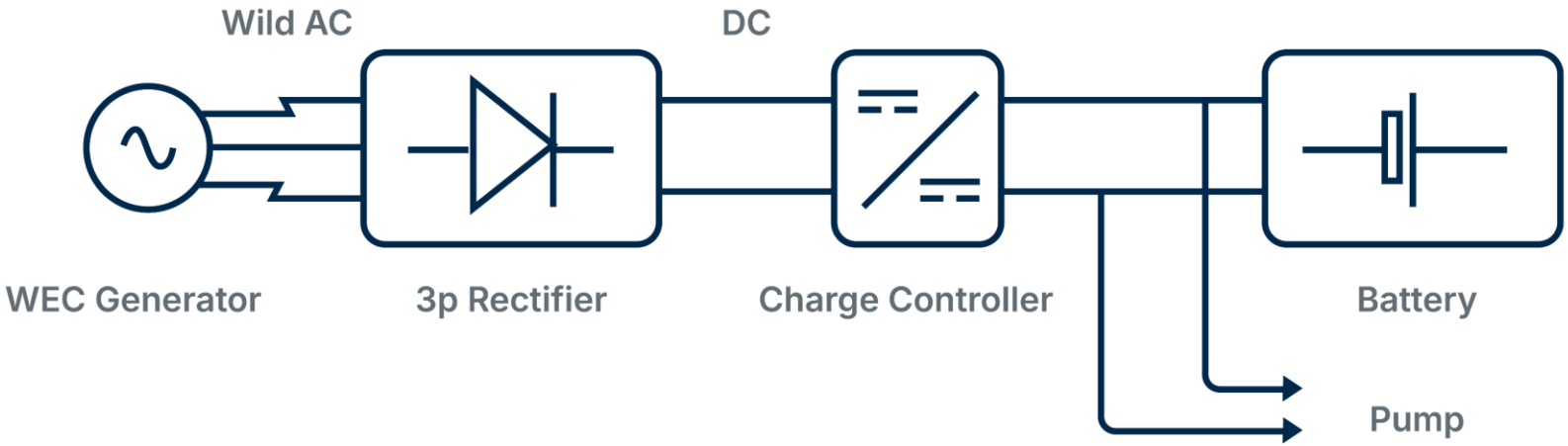
Design: Mechanical

Reverse-Osmosis System

- Two off-the-shelf Spectra reverse osmosis units—commonly used on boats—desalinate seawater into fresh drinking water.
- Clark pumps used for energy recovery and intensification.
- Hydraulic accumulators smooth pressure spikes.

Photo by Scott Jenne, NLR

Design: Electrical



Design: Electrical

Generator

- 3 kW
- 1,000 rpm
- 25 A
- 120 V

Batteries

- Lithium-ion iron phosphate
- Two 24-V parallel
- 200 amp-hours capacity

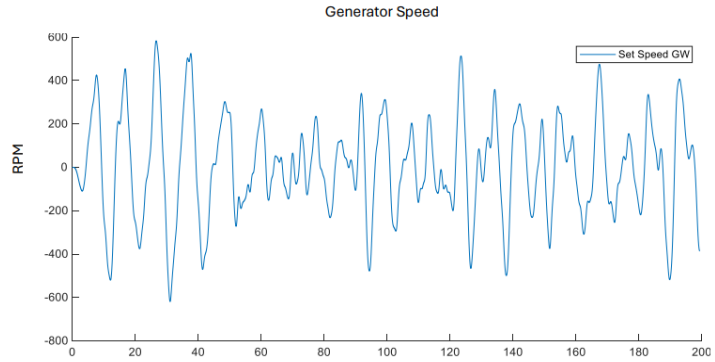
Charge Controller

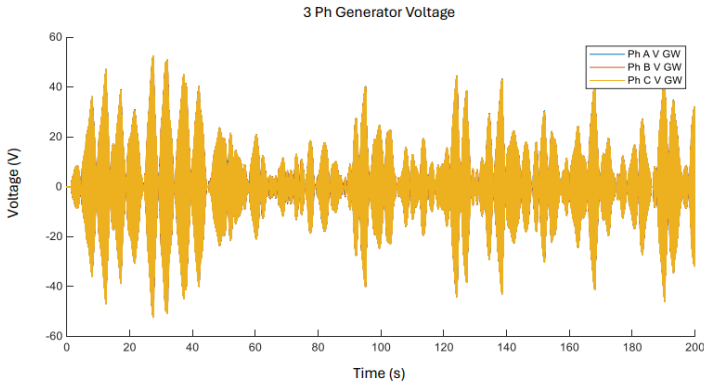
- Off-the-shelf from Midnite Solar
- Buck converter topology
- 1.8-kW rating
- Replaced with custom device

Design: Electrical

Challenges

- Inconsistent and pulse-based power delivery.
- Renewable power delivery changes over hours, days, and seasons. A wave changes over seconds.
- High peak-to-average power ratio.
- Peak-to-average power ratios for waves can exceed 10x those of wind.

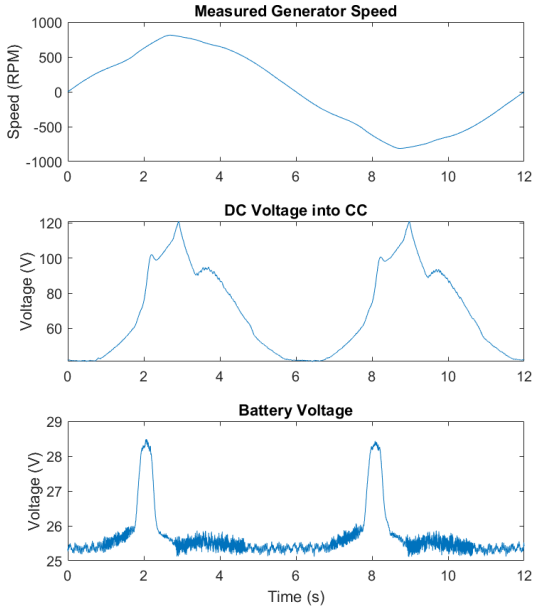


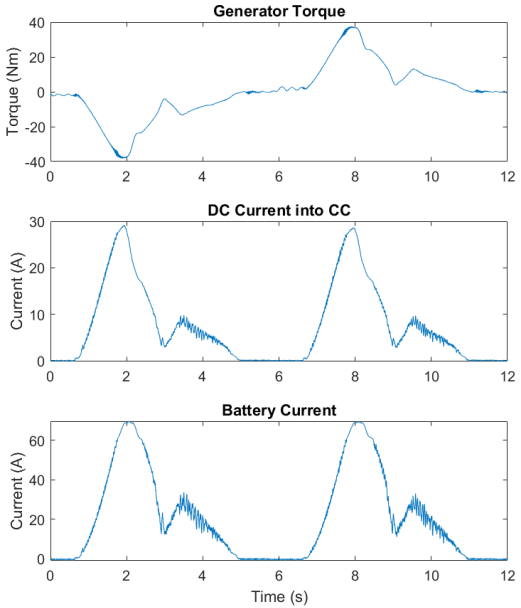


Design: Electrical

Cut-in Voltage

- Buck converters can only step down DC voltage, limiting range.
- Battery is only able to charge at input voltages greater than the battery charge voltage.

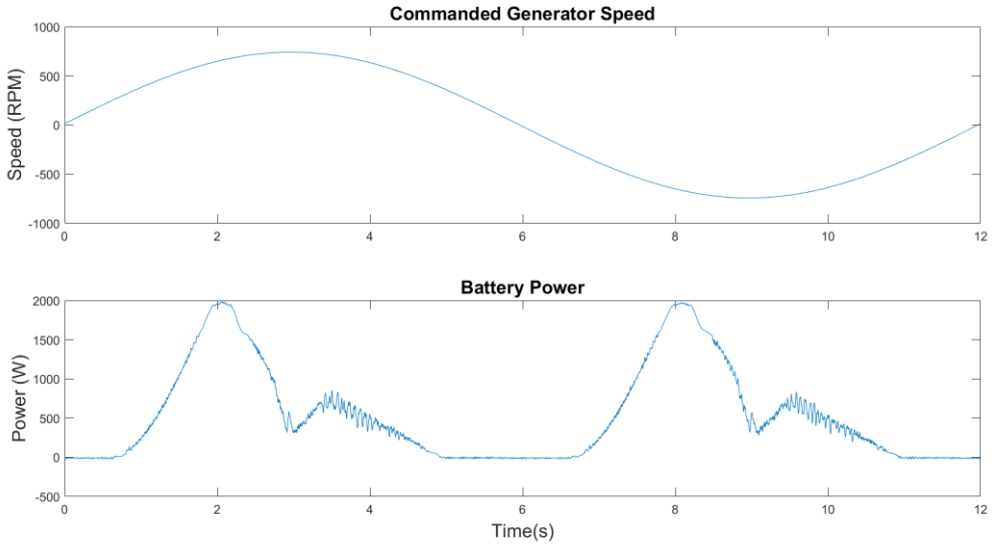




Design: Electrical

Overshoot

- Under moderately aggressive conditions, the current delivered to the battery exceeded the command by >40 A.
- Shorter wave periods and higher amplitudes exaggerate overshoot.
- Caused by improperly tuned controller applied to wave



Design: Electrical

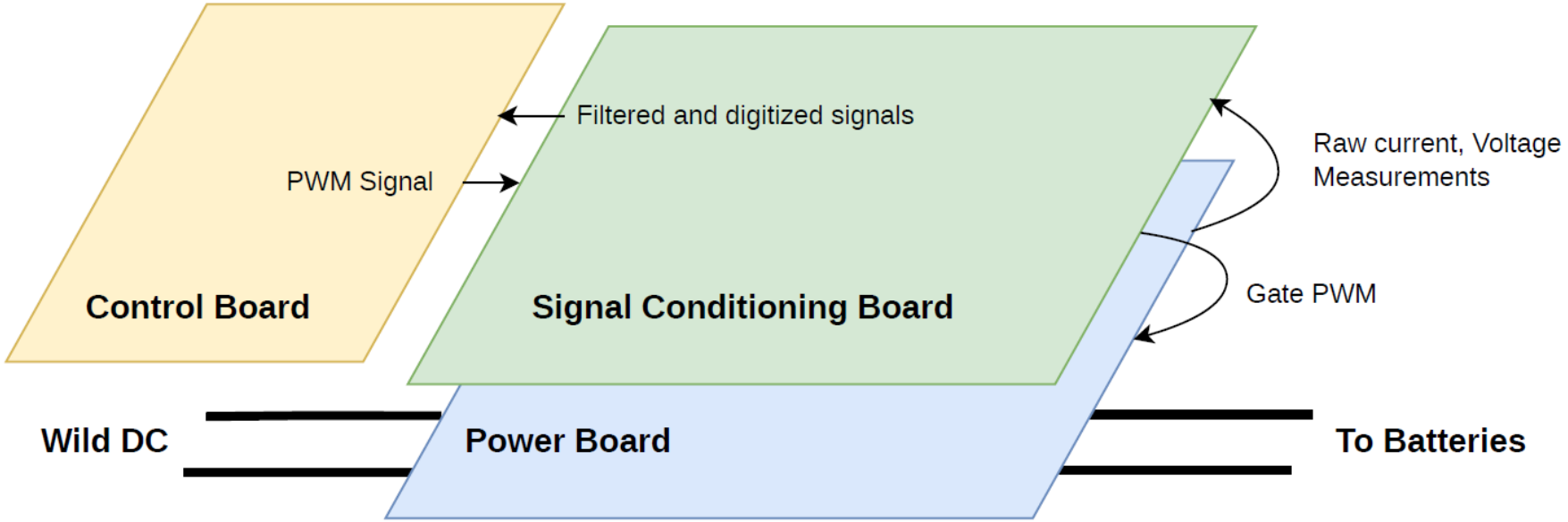
New Custom Controller

A custom charge controller was built in-house to improve:

- **Cut-in voltage** by replacing the buck topology with buck/boost
- **System response** by building firmware to quickly read voltage/current and tuned for quick wave inputs
- **Future research potential** by including onboard measurements and utilizing an FPGA for system control with plenty of I/O expansion.

Design: Electrical

Charge Controller Architecture



Design: Electrical

Power Board

- Buck/boost circuit
- V/I measurements
- Hardware fault protection

Signal Conditioning Board

- Filter analog signals
- Digitize measurement via SPI protocol
- Isolate and drive the MOSFET gate high/low
- Manage fault communication

Control Board

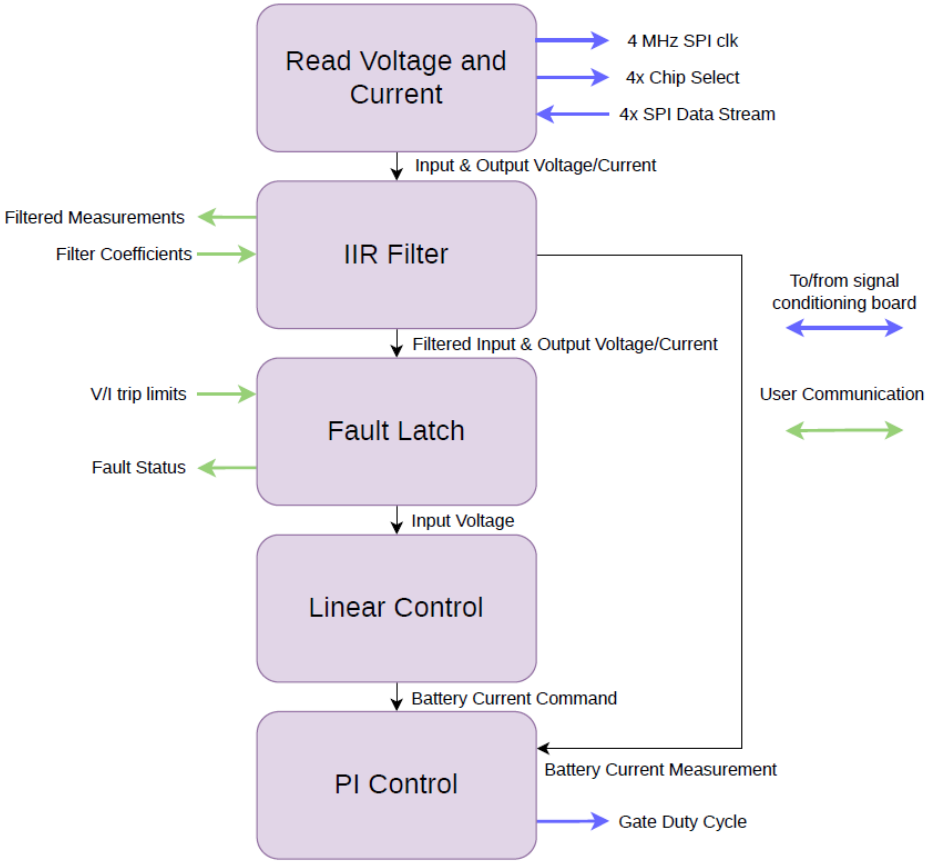
- Cyclone FPGA board
- Read in voltage/current and command the gate
- Software fault protection

Photo by Alec Schnabel, NLR

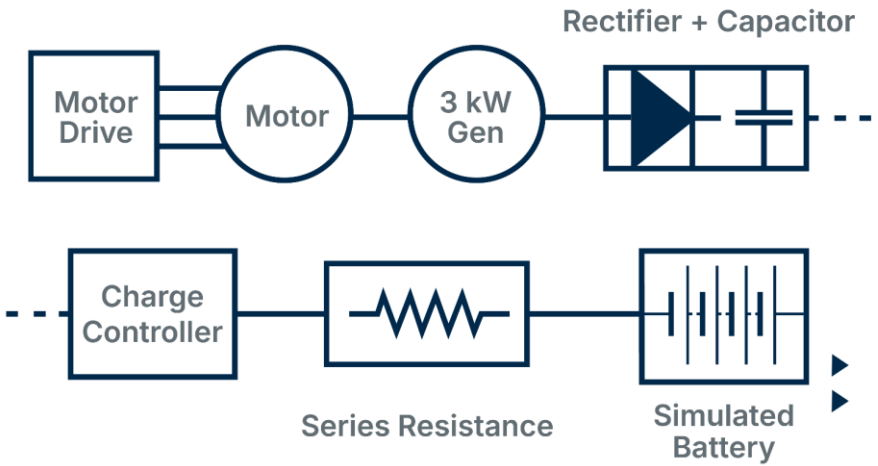
Design: Electrical

Software

- Software processes voltage and current measurements, monitors for faults, and commands the MOSFET gate.
- Simple linear damping control is implemented:
  - Output battery current is linearly proportional to input DC voltage (bulk charging stage).
  - Control is deliberately simple.



Design: Electrical



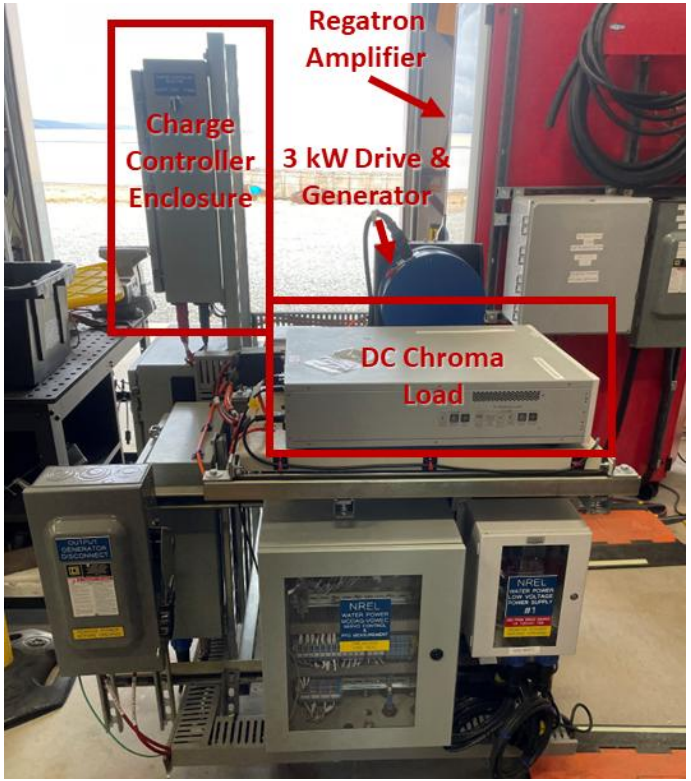
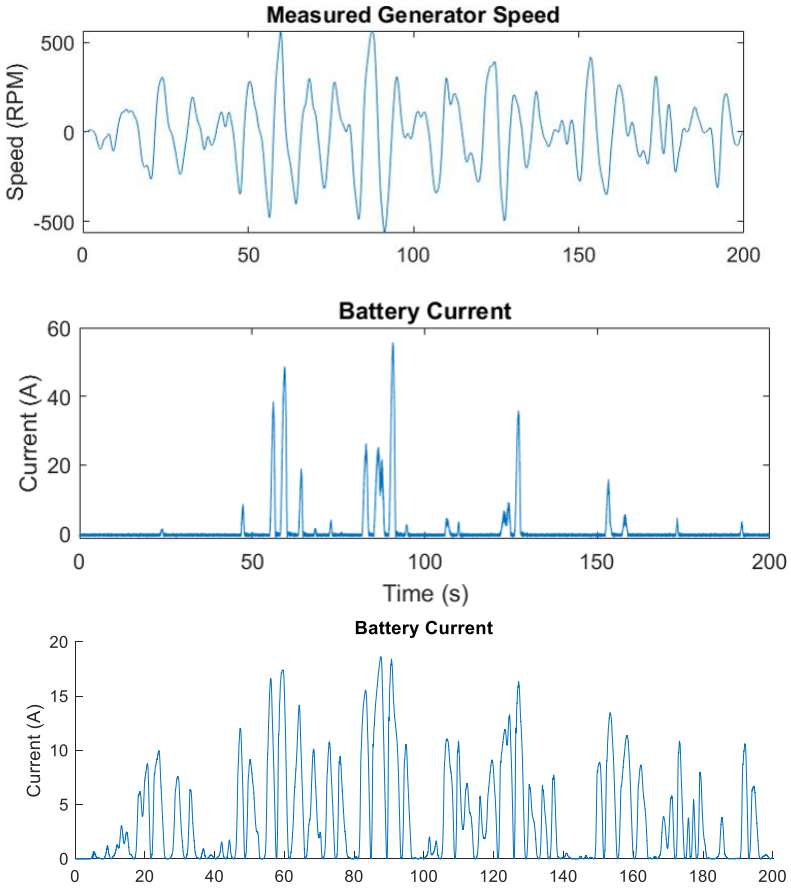


Photo by Alec Schnabel, NLR

Design: Electrical

In-Lab Results

- Identical sinusoidal and irregular wave cases programmed into 3-kW dynamometer.
- 3–8x power capture increase depending on wave case.
- Ongoing tuning and control optimization.



Deployment

Deployments

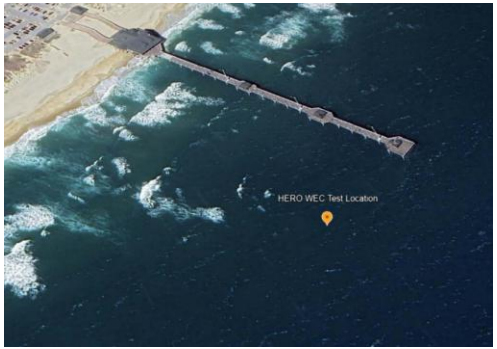


Image from Google Earth

Photo from John McCord, Coastal Studies Institute

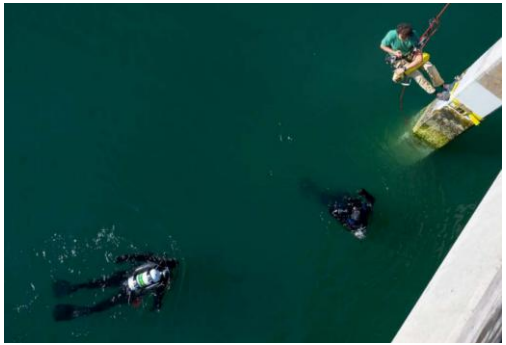


Photo from John McCord, Coastal Studies Institute

Photo from John McCord, Coastal Studies Institute

Photo from John McCord, Coastal Studies Institute

Photo by Andrew Simms, NLR

Lessons Learned

Planning & Preparation

- Plan for independent multistage deployments.
- Maintain flexible schedules for weather windows.

Mooring & Anchoring

- Carefully design anti-spin mooring and reduce shock loads.
- Heavy anchors can become deeply buried over time.

Drivetrain & Electrical

- Always maintain load on the generator.
- Use multiple rigid winch line attachment points to avoid sharp edges.

Design

- Minimize free-hanging components.
- Reduce underwater connections.
- Use rigid hose connections over flexible.

Testing Philosophy

- Numerical models can miss real-world failure modes.

Microgrid Integration

Microgrid Integration

Microgrid Needs

- Remote communities rely on traditional generation sources at higher cost and challenging logistics.
- Diversity in generation increases resiliency and reliability.
- Storable energy is critical for maintaining year-round energy demand for far-north communities.

Wave Energy Meets Microgrid Needs

- Wave/tidal energy is consistent and requires no consumables.
- Coastal communities can add an abundant energy source to their portfolio of generation.
- Hydrogen storage with wave energy is an emerging field of research to provide long-term energy storage.

Microgrid Integration

HERO WEC's Role in Meeting Microgrid Needs

- HERO WEC provides a flexible test bed for researchers to study grid integration of WECs.
- Small-scale microgrids can interface with HERO WEC directly.
- Power hardware-in-the-loop (PHIL) techniques scale up microgrid integration research.

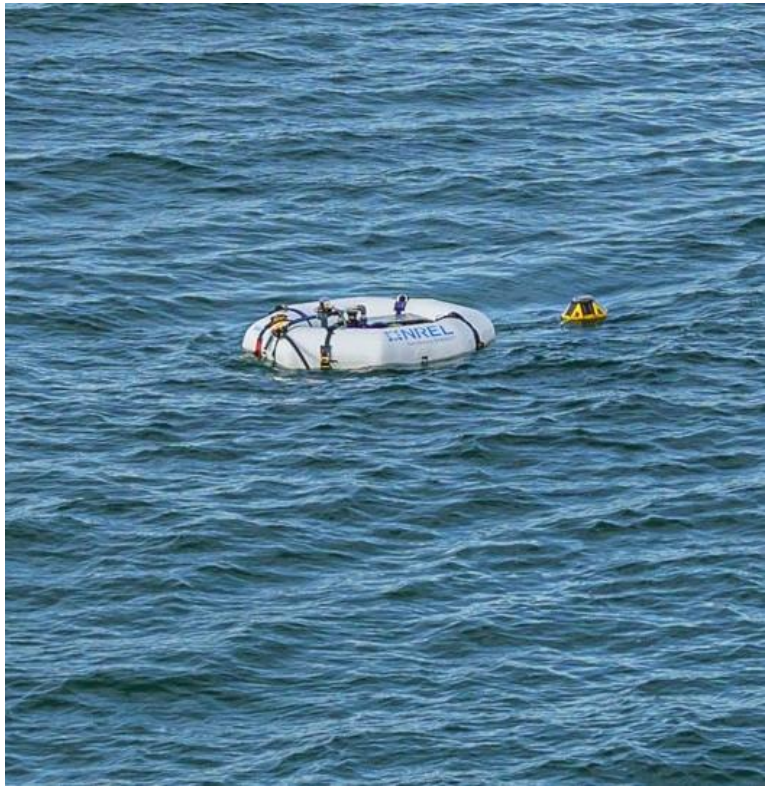
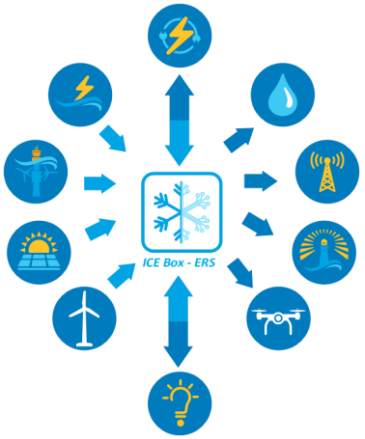


Photo by Scott Jenne, NLR

Microgrid Integration

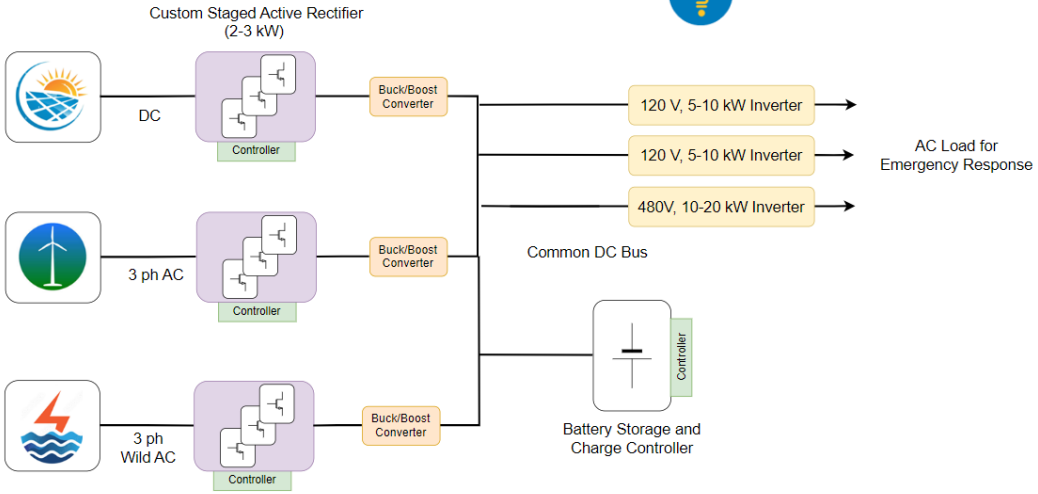
Small-Scale Microgrid Integration

24-V DC bus can integrate power and energy storage to “nanogrid” applications



Use cases:

- Ocean observation.
- Emergency Response.
- Autonomous underwater vehicle charging.

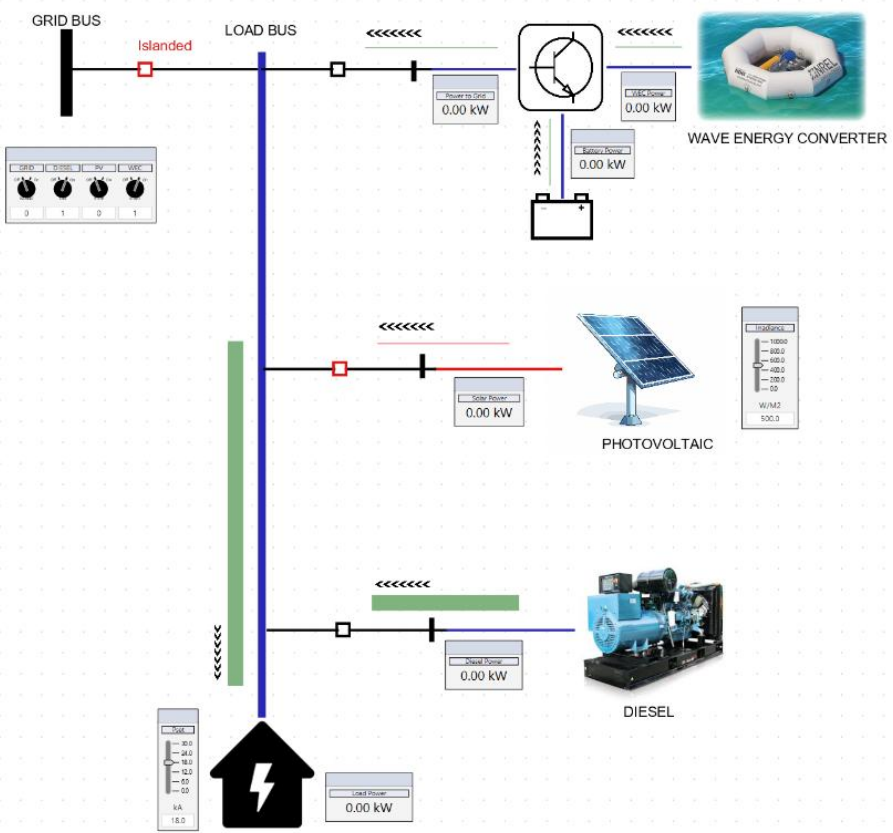


Microgrid Integration

PHIL Scaling

WEC inputs and challenges can be scaled to meet research needs.

Photo by Alec Schnabel, NLR



Large-Amplitude Motion Platform (LAMP) Integration

NLR's LAMP brings mechanical challenges into the test loop.

Photo by Josh Bauer, NLR

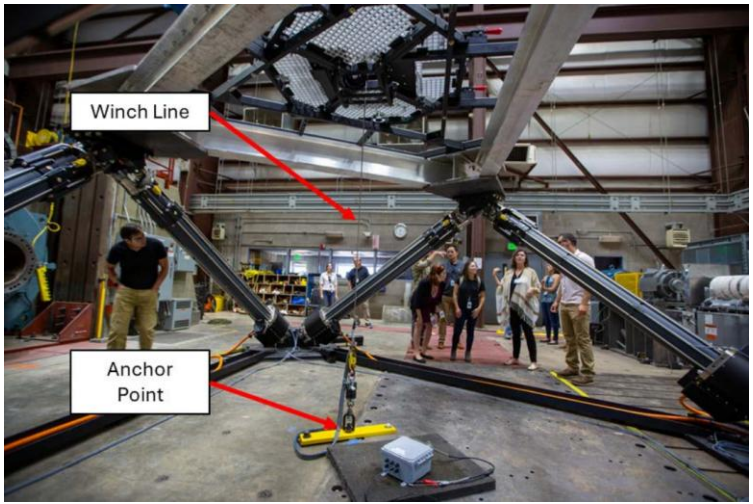


Photo by Josh Bauer, NLR

Future of HERO WEC

Looking Ahead

HERO WEC Redesign Effort – Electric

- Charge controller:
  - Clean-sheet redesign of hardware and software.
- Dump load:
  - Automatically switches to dump load to maintain electrical load during fault.
- Generator redesign:
  - Generator with higher voltage output and cleaner back electromotive force.

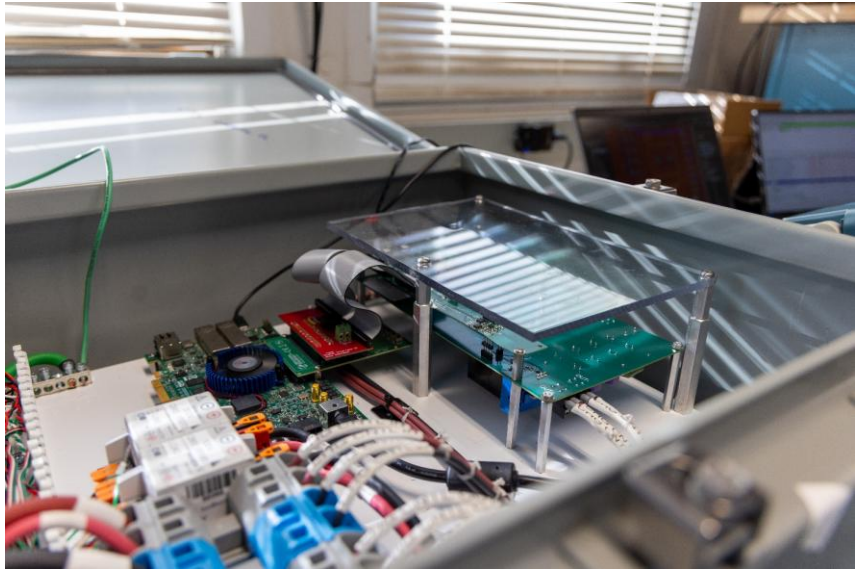


Photo by Taylor Mankle, NLR

Looking Ahead

HERO WEC Redesign Effort – Mechanical

- New hydrodynamic design:
  - Welded “elongated octagon” replacing inflatable octagon raft.
- Frame redesign:
  - Custom frame with intentional component housing.
- Belt-driven winch:
  - Cable replaced with belt for reduced bending stress and longer fatigue life.

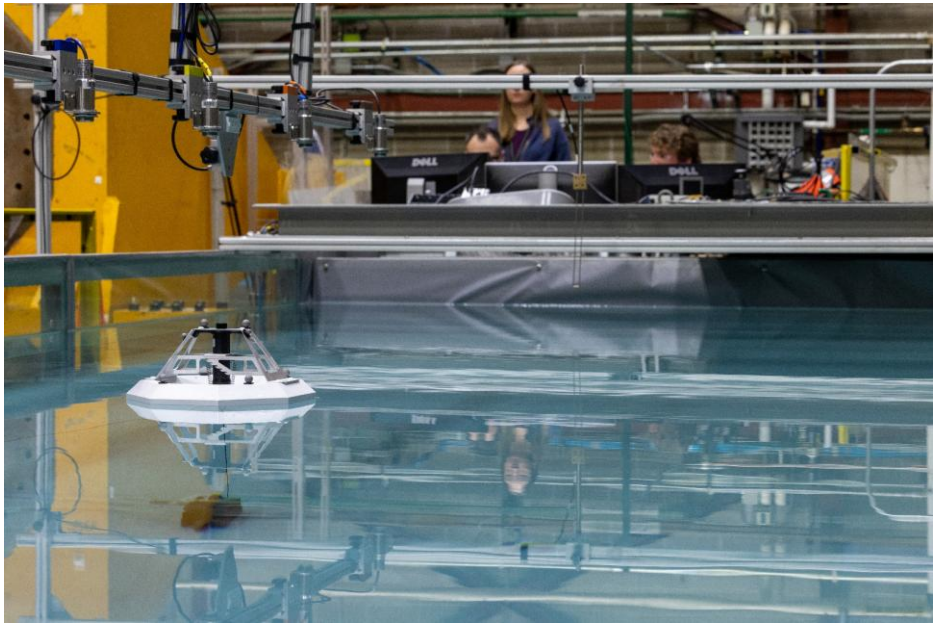


Photo by Gregory Cooper, NLR

Looking Ahead

Photo by Joshua Bauer, NLR

Next Steps

- LAMP testing
  - Full-system electrical and hydraulic configurations to be put on LAMP.
- Control optimization
  - Numerical modeling, dyno testing, and LAMP testing will inform new control.
- Deployment
  - Fourth deployment of HERO WEC aiming for 2027.

Looking Ahead

HERO WEC as an Asset

- System was designed with flexibility in mind
- HERO WEC power take-off often used in PHIL testing
- Open-source data collection
- Modular design to slot-in new components and ideas.

Photo from John McCord, Coastal Studies Institute

Save the Date!

- **Advancing Power Electronics for Wave Energy Converters**
  June 8, 2026, 12 p.m. MT

- **Microgrid Power Hardware-in-the-Loop Modeling**
  August 10, 2026, 12 p.m. MT

Q&A

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NLR/PR-5700-100101

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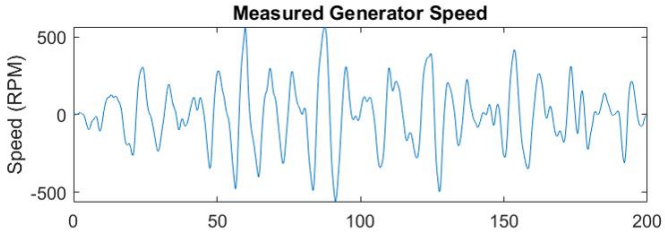

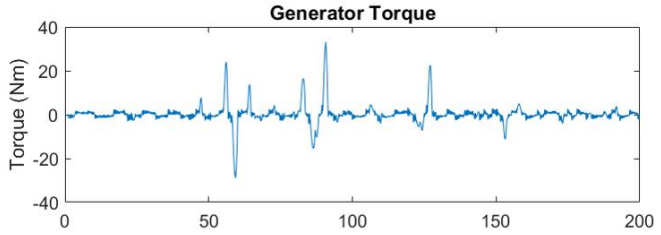

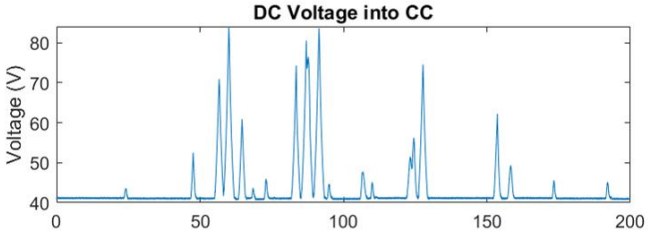

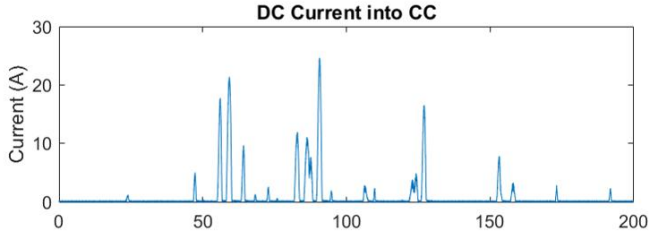

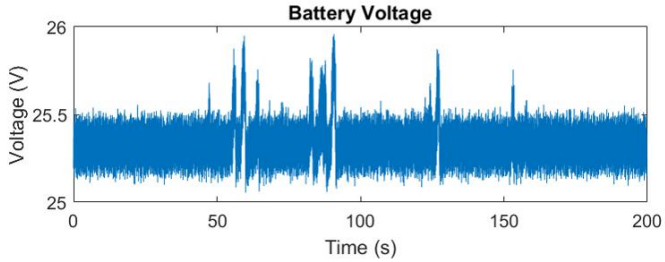

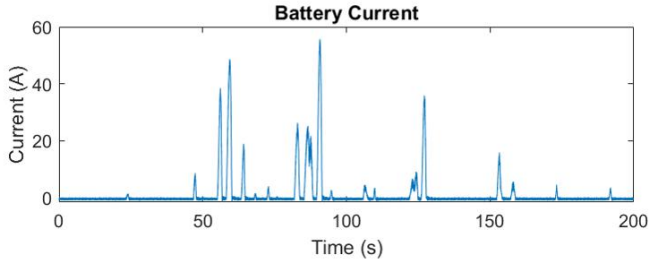
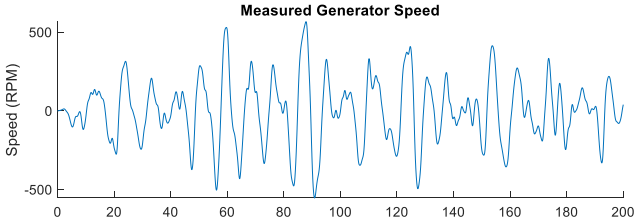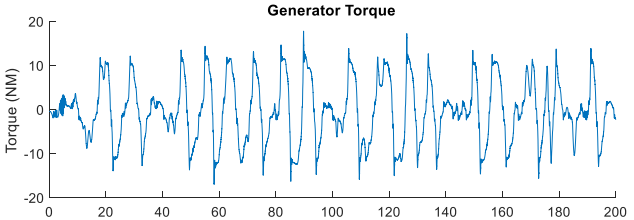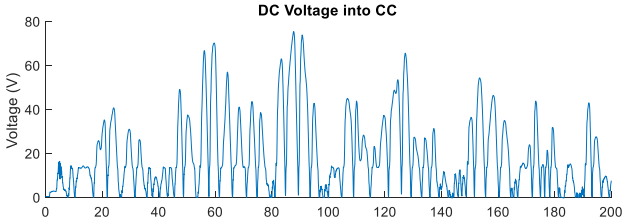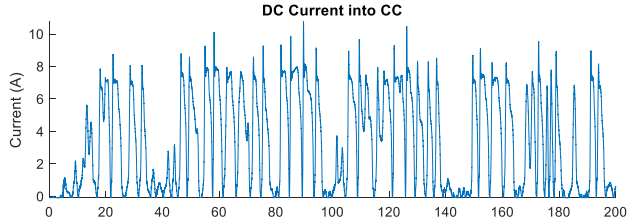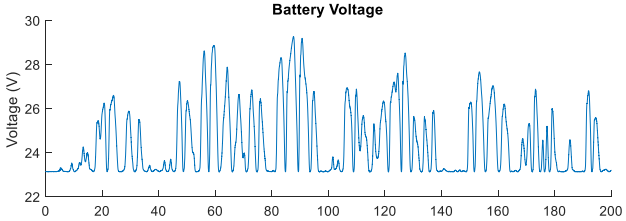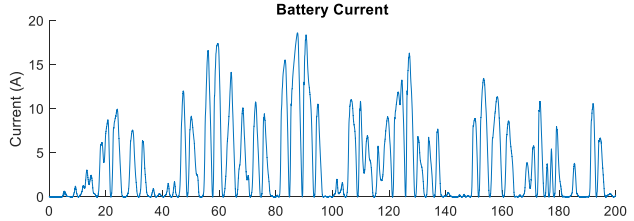
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