Hybrid Energy Storage Validation for Marine Renewable Energy Microgrids through RTDS and Typhoon HIL Co-Simulation

1.1 Background/Objectives

Marine renewable energy (MRE) microgrids are emerging as a practical option for coastal grids, islanded communities, and blue-economy facilities. The primary generation sources like tidal turbines and wave energy converters are inherently variable: tidal output follows multi-hour cycles, while wave output fluctuates second-to-second with sea state. No single storage technology rides through both timescales efficiently, so a hybrid energy storage system (HESS) is used in which the power demand is split by frequency content: a battery absorbs the slow, bulk energy shifts, while a supercapacitor handles the high-frequency transients that would otherwise shorten battery life. The resulting microgrid aggregates the tidal generator, the wave energy converter, the battery, and the supercapacitor on a common DC bus, with a grid-side converter linking the DC bus to the AC network.

Validating such a system on a single real-time simulator is difficult: the DC side requires microsecond switching fidelity for the source-side converters, the HESS dispatch, and the frequency-splitting control, while the AC side requires utility-grade electromagnetic-transient (EMT) models for transformer saturation, machine dynamics, and protection coordination. This work develops a real-time co-simulation framework that resolves both domains without compromise and uses it to study the coordinated response of the hybrid storage system under grid disturbances.

1.2 Approach/Activities

The DC side is split across two Typhoon HIL 606 units. The first hosts the marine generation subsystem: tidal turbine, wave energy converter, and their primary controls. The second hosts the storage and load subsystem: battery, dual-active-bridge converter, supercapacitor, and DC load. The fixed-step Typhoon HIL solver and its controller-hardware-in-the-loop interfaces allow the storage management logic to be exercised at full switching fidelity.

The AC grid runs on an RTDS NovaCor Light, which supplies the utility-grade EMT models. The two platforms are coupled through a real-time interface whose design governs the numerical stability, latency, and energy conservation of the co-simulation. Voltage sags, frequency events, and fault ride-through scenarios are injected from the RTDS side to drive the grid-side converter and excite the full microgrid response.

1.3 Results/Lessons

The framework identifies the operating conditions under which two-platform co-simulation is required rather than a single real-time platform. The resulting testbed is a programmable environment for marine renewable energy integration, hybrid storage control design, and grid-code verification spanning the power grid to blue-economy markets. Future work will extend it with power-hardware-in-the-loop coupling to physical converter prototypes, communication-aware interfaces for distributed energy management, and adaptive interface compensation for long-duration scenarios.

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