project eWAVE

Efficient HV-electric modular battery and distribution systems for sustainable WAterborne VEssels

Deliverable D3.1: Specifications of Battery system

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PROJECT ABSTRACT

The maritime sector faces challenges in transitioning to sustainable, all-electric vessels. Key obstacles include low energy density in current battery systems, safety concerns, and the need for durable, sustainable materials. Economic viability also remains a significant barrier for widespread adoption. To address these issues, the EU-funded eWAVE project brings together 18 experts from research, technology, and shipbuilding to advance high-voltage (HV) technology for electric vessels. By developing high-energy-density batteries, scalable modular systems, and an integrated safety concept, eWAVE aims to enhance the sustainability, safety, and efficiency of maritime transport. The project will also explore circularity through bio-based materials and recycling, supporting the EU's goal of reducing the environmental footprint of shipping.

Public Summary

D3.1 presents a battery system specific baseline for WP3. It consolidates requirements and provides a coherent concept for the cell and the 24series module, the Modular Base Unit with embedded Modular Multilevel Converter, the string control, the safety concept, and the monitoring and data paths. The reference cell class is P73. The baseline targets a string operated around 1.5 kV direct voltage and is prepared as a shared and traceable basis for development and procurement.

The deliverable outlines:

1. **Methodology and scope –** Deliverable "D3.1" compiles and structures the detailed battery system requirements established in the previous project phase. The document defines key technical specifications – including the battery module architecture, performance targets, and interface requirements – that form the concept baseline for the battery system. These specifications guide the WP3 development and serve as a foundation for upcoming procurement decisions. D3.1 also emphasizes requirements traceability.

2. **Concept Architecture –** The battery system adopts a modular architecture built from identical Modular Base Units (MBUs), each containing one battery module and an integrated bidirectional converter (MMC). MBUs connected in series form a battery string that delivers the required high DC voltage; each string is managed by a String Master Controller (SMC) which orchestrates all MBU operations over a deterministic real-time bus. The SMC handles normal operation and performance control (e.g. current regulation and pre-charging). The primary safety chain is implemented by the wired BMS and the SMC; the system does not depend on the wireless path. The Wireless Safety Controller is an optional demonstrator add-on that operates in parallel to evaluate a wireless monitoring concept and add diversity. When present, it monitors critical cell parameters over a dedicated wireless link and can issue a shutdown request via a defined interface, but it neither replaces nor is required for the primary safety functions performed by the wired BMS and SMC. Real-time control and safety therefore remain on the same primary layer (BMS/SMC), with the wireless path providing auxiliary, independent cross-checks.

3. **Module and Converter Specification –** Each Battery Module (BatM) with lithium-ion cells in series and includes dedicated monitoring electronics; Cell Monitoring Units (CMUs) are used per module to measure all cell voltages and temperatures and to perform balancing. Safety considerations impose strict thermal propagation constraints – the layout includes defined thermal limits and physical safeguards (barriers, venting features, and spacing) to prevent or contain any module thermal runaway events. The MBU's integrated converter is specified to handle inrush current limiting and output ramp-up. These module and converter specifications serve as design inputs for WP3, ensuring the battery system meets performance and safety requirements.

4. **Monitoring, Control, and Safety –** The Battery Management System (BMS) is structured with a primary wired monitoring/control chain and a parallel wireless safety chain for redundancy. In the primary path, each module's CMUs gather cell measurements (voltage, temperature, etc.) and feed them to the MBU's controller; these data support real-time management and state estimation algorithms – State of Charge (SoC), State of Health (SoH), and State of Safety (SoS) – running on the MBU and/or SMC. In parallel, a dedicated Bluetooth Low Energy (BLE)-based safety controller continuously monitors critical cell data via a wireless link directly from the dedicated and/or the available CMUs, independent of the main control bus. This safety

controller acts as an immediate backup: it will detect faults and issue shutdown commands. Together, the wired BMS and the wireless safety path provide a layered monitoring and protection system, separating normal control tasks from fail-safe protection functions.

5. **Communication and Data Interfaces –** D3.1 delineates a clear split between the real-time control network and the IT/data network in the battery system. The real-time domain connects the SMC with all MBUs/MMCs (and the safety controller) in a closed, deterministic loop for fast control and protection, while a separate information domain links the Battery System Controller Unit (BatSysCU) and/or SMC to the ship's Condition Monitoring System (CMS) and higher-level systems (SCADA/EMS) for telemetry and non-critical data exchange. A strict "default-deny" access policy is enforced: external systems (e.g. SCADA or EMS) cannot directly address any MBU or converter; all data and commands must pass through the BatSysCU and/or SMC gateway, with only explicitly allowed communications (such as the BatSysCU forwarding data to the CMS) permitted. The interface definitions – including the base and extendable CMS data tags and signal mappings – are documented in the project's interface control document ICD-D, ensuring that the battery system's real-time signals and monitoring data are consistently routed through the BatSysCU to the ship's systems. This architecture maintains a secure segregation between real-time control and IT-level data access, aligning with cybersecurity and safety requirements.
6. **Traceability –** D3.1 maintains WP3 traceability of the system requirements by linking the battery system related WP3 requirements from deliverable D2.2. For every requirement, the document specifies how it will be achieved (the development feature). This traceability matrix (tables) ensures that the development decisions in WP3 can be traced back to the agreed requirements.

In conclusion, Deliverable D3.1 provides a baseline technical reference for the battery system development and procurement preparation activities in WP3. By specifying the module, converter, and BMS (including safety) concept in detail, it enables the WP3 to proceed with development and component procurement. The document remains technically focused and strictly aligned with the project's scope in the Grant Agreement, supporting WP3 development needs without disclosing any implementation-specific intellectual property.