ENERGETICS

Ammin/DENERG/Vulkan - Advanced Hybrid Electric Propulsion and Energy Management for Waterborne Transport Systems

Funded By	VULKAN ITALIA S.R.L. [P.iva/CF:01318430061] Dipartimento DENERG Politecnico di TORINO [P.iva/CF:00518460019]
Supervisor	MISUL DANIELA ANNA - daniela.misul@polito.it
Contact	MIRETTI FEDERICO - federico.miretti@polito.it
Context of the research activity	The project aims to optimize hybrid electric propulsion for maritime transport by addressing challenges related to energy management, thermal management, and powertrain design. The objective is to develop scalable solutions and advanced digital tools for real-time monitoring and optimization of system performance, supporting a sustainable transition backed by concrete data.
	This research is carried out in collaboration with Vulkan Italia, a company involved in the development of hybrid powertrains for waterborne transport. The project aims to develop an integrated technological and methodological framework for the design, control, and evaluation of hybrid electric waterborne transport systems, with a focus on waterbuses, ferries and similar vessels operating in coastal areas and inland waterways. The work will address key limitations in existing propulsion and energy systems by combining multidisciplinary approaches across energy systems engineering, control theory, and digital twins. The main objectives of the research program are: 1. Design and optimization of hybrid propulsion architectures The project will explore complex hybrid electric propulsion configurations combining internal combustion engines (ICE), battery systems, fuel cells, and electric motors. Trade-offs between different powertrain topologies will be studied using performance, well-to-wake emissions, and lifecycle cost as metrics. Simulation models will be developed to support these design choices and validated using available experimental or operational data. A powertrain design framework will be established using dynamic programming to optimize the energy management strategies (EMS) associated with each topology under investigation. Furthermore, the integration of thermal management into propulsion system

Objectives	design will be explored. Efficient cooling and thermal control of batteries, power electronics, and auxiliary systems will be addressed, with a focus on waste heat recovery and optimal energy distribution. Co-simulation of electrical and thermal subsystems will support the development of energy-efficient architectures tailored to the operational patterns of the vessel. 2. Development of smart energy management strategies (EMS) Efficient operation of hybrid systems depends on real-time control of energy flows among sources, storage systems, and propulsion loads. The research will develop and test energy management algorithms, including rule-based and optimization-based approaches (e.g. dynamic programming and ECMS), that dynamically balance fuel efficiency, emissions, and battery degradation. Scenarios such as peak shaving, shore power integration during docking, and auxiliary energy sources such as solar panels will be analyzed to maximize overall system efficiency and environmental benefit. 3. Implementation of a digital twin for predictive monitoring and control A core innovation of the project lies in developing a digital twin of the hybrid waterbus system. This real-time virtual model will mirror the physical system's state, enabling predictive diagnostics, anomaly detection, and performance optimization. It will integrate sensor data, simulation models, and control strategies into a single interface for operators and engineers. The digital twin will also serve as a platform for testing EMS strategies and conducting what-if analyses without interfering with operations. Insights from the research will contribute to the broader topic of sustainable maritime transport. The project aims to provide technical evidence that informs policymakers and design guidelines. By linking engineering developments to environmental and economic performance metrics, the work will support informed decision-making by public authorities and industry stakeholders. In summary, this research goes beyond the state-of-the-art by developing a tightly integrated approach to hybrid propulsion, energy and thermal management, and digital modeling for waterborne transport. The combination of technical depth and system-level perspective aims to overcome existing barriers to adoption and provide scalable solutions aligned with future sustainability goals.

Skills and competencies for the development of the activity	• Experience in design and simulation of hybrid and electric propulsion system, preferably for waterborne applications. • Theoretical background in energy management strategies for hybrid powertrains. • Experience with MATLAB/Simulink and multi-physics simulation environments such as Simscape.