Research theme title:
OPTIMIZATION AND CONTROL STRATEGIES FOR POWER MANAGEMENT OF MARINE HYBRID PROPULSION SYSTEMS

Description:
Environmental concerns are pressing the shipping industry to adopt energy efficiency-oriented measures to tackle greenhouse gas emissions and move to effective and environmentally friendly power systems [1]. This implies redesigning the system configuration, the machinery, and the power management strategies. In particular, the current trend in the design of more efficient and versatile ships is leading to the development of hybrid propulsion systems, which use internal combustion engine, electric motors, battery and fuel cell storage systems, integrating intelligent power generation strategies [2].

In this context, the proposed PhD project aims at defining a power management system capable of supervising different onboard production systems and optimizing their performance thanks to a Digital Twin, while monitoring actual states, analyzing historical states, and predicting future behaviors, in order to maximize the overall efficiency of assets and make immediately corrective decisions in case of unexpected deviations.

The research will be conducted in accordance with the following main activities:

1. DEFINITION OF HYBRID PROPULSION SYSTEM CONFIGURATIONS BASED ON LOAD PROFILES AND TOPOLOGIES

This activity aims at defining innovative hybrid propulsion configurations by integrating different existing energy sources based on the vessel topology, and leveraging on the potential offered by the on-going development of battery technologies as well as hybrid drives, DC-grid solutions, shore charging, automation solution, and power-take-in (PTI) motors. The vessel operational profile, type, and function as well as the corresponding power requirements will be considered to specify the optimal propulsion system configuration. In particular, the operational profile will identify the power demand required for navigation over the different expected vessel operation modes.

2. IMPLEMENTATION OF A DIGITAL TWIN

This activity consists of:

- define the Digital Twin concept with the final aim of designing and modeling different hybrid propulsion architectures, including various types of physical objects corresponding to the power system components, each being simulated with the appropriate level of granularity in terms of dynamics, states, and interconnections;
- propose a conceptual framework for designing, implementing, and supporting the entire life cycle of physical objects integrated in the power system;
- validate the conceptual framework in reference to a real hybrid propulsion solution, including all the aspects related to use of a Digital Twin in planning, monitoring, controlling, and optimizing the power system operations.

3. TEST OF A HYBRID PROPULSION ARCHITECTURE WITH CONTROLLABLE LOADS

This activity aims at testing a prototype of the above defined power management strategies for hybrid propulsion systems. The considered configurations will include the presence of common components such as combustion engine, fuel cell, battery, power converters, as well as the integration of these components in the overall system, thus enabling the assessment of technical specifications and the test of different conditions and scenarios remotely controlled by the corresponding Digital Twin framework. The prototype of the power management system will be also connected to a real propulsion testbed in order to enhance the effectiveness of the optimization and control strategies through the use of the real data gathered by the hardware platform.

The research activities will be conducted in collaboration between the Decision and Control Laboratory of Polytechnic of Bari and Isotta Fraschini Motori S.p.A., which is an Italian company specialized in advanced solutions for hybrid propulsion systems in marine applications. Moreover, the PhD project is of absolute centrality for the Italian National PhD Program in Autonomous Systems, given that the efficient and sustainable development

of propulsion systems requires innovative approaches for the management and control of power generation sources, energy storage systems, and smart loads.

Finally, it is worthwhile mentioning that the objective of the PhD project is aligned with the national development strategies as well as the international research directions, which are undergoing radical transformations, enabled by the progressive and pervasive adoption of digital technologies, and their integration with energy storage and production technologies. In particular, the project is coherent with the strategic pillars and horizontal principles of the Italian National Recovery and Resilience Plan, being fundamental for the Mission 2 "Green revolution and ecological transition".

References:

[1] Jaurola et al. 2019 Optimising design and power management in energy-efficient marine vessel power systems: a literature review, J. Marine Eng. Tech. 18:2, 92-101.

[2] Inal et a. Hybrid power and propulsion systems for ships: Current status and future challenges 2022 Renewable and Sustainable Energy Reviews 156, 111965.

Type of scholarship:

DM 117/2023 – Project on PNRR (Italy's Recovery and Resilience Plan)

Hosting University

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Study and research period outside the Hosting Institution:

Study and research period at the company:
Isotta Fraschini Motori S.p.A. (https://www.isottafraschini.it/)