DESIGN OF ADVANCED POWER MANAGEMENT STRATEGY FOR HYBRID ZERO-EMISSIONS SHIPS

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Keywords: End-use technologies

ABSTRACT

Hydrogen-powered fuel cell ships have emerged as a promising alternative to traditional internal combustion engine ships fueled with fossil fuels, particularly heavy fuel oil, garnering significant attention from maritime manufacturers worldwide. However, fuel cell systems have some drawbacks, such as high costs and slow response times. Hybridization can be a viable solution to mitigate the aforementioned disadvantages. The purpose of this work is to present a shipboard hybrid power system featuring proton exchange membrane (PEM) fuel cells and battery energy storage systems. To regulate the power flow within the ship's power and propulsion system, an advanced energy management technique is developed. This technique determines the optimal output power for both the fuel cell system and battery based on the power required by the loads and propulsion systems. The overall system is modeled under the MATLAB-Simulink environment, and numerical simulations are performed to validate the proposed energy management approach for real ship driving cycles. The results demonstrate the suitability of the proposed strategy and the advantages of adopting a hybrid fuel cell/battery as an alternative power system, paving the way for more environmentally friendly ships.

SYSTEM AND ENERGY MANAGEMENT DESIGN

Figure 1 shows the single-line block diagram of the proposed system. The system comprises an on-board stored hydrogen-powered PEM fuel cell system and a battery energy storage system (BESS), which are connected to the DC bus through a boost DC/DC converter and a bidirectional DC/DC converter, respectively. A DC/AC converter is employed to connect the propulsion motor to the DC bus, while service and hotel loads are directly connected to the DC bus. The overall loads are emulated using real data extracted from an operating ship. The design of system components is selected according to the design equations provided in [1], [2], and [3].
The advanced energy management system designed allows for controlling the energy produced by the power sources by monitoring the power demand of the loads and propulsion motor, state of charge of the battery, and fuel cell power level to avoid their degradation.

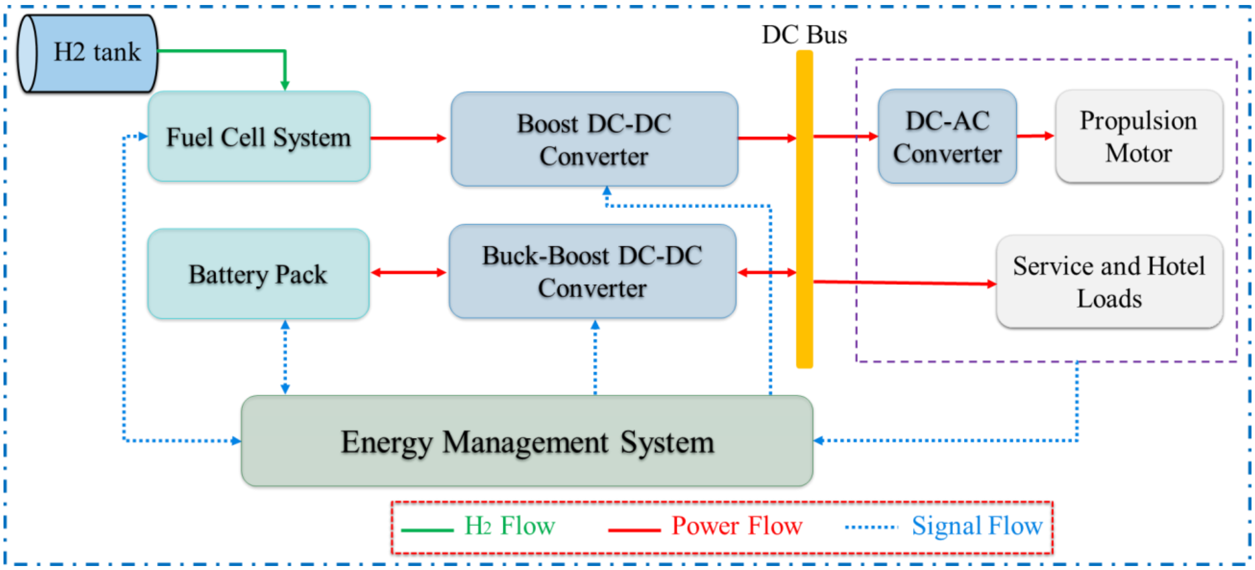

Figure 1. Single-line schematic of the proposed system

Acknowledgements

This work was performed within MoZEES, a Norwegian Centre for Environment-friendly Energy Research (FME), co-sponsored by the Research Council of Norway (project number 257653) and 40 partners from research, industry, and public sector.

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