NAUTILUS, Nautical Integrated Hybrid Energy System for Long-haul Cruise Ships

MAN ES Battery & Main Controller Container as Part of the Modularised Functional Demonstrator

Mathias Moser (1), Fabian Grimm (1), Alexander Reiter (1), Margarita Kalogeropoulou (1), Rafael Goldbeck (1), Santiago Salas Ventura (2), Cem Ünlübayir (3)

(1) MAN Energy Solutions, (2) German Aerospace Center (DLR), (3) RWTH Aachen University

Motivation & Role in the Project

According to International Maritime Organization (IMO) regulations, there is an urgent need for decarbonization in the maritime sector, with 2050 set as a decisive year for achieving a significant reduction in total greenhouse gas (GHG) emissions, as shown in Figure 1. As a leading engine manufacturer and system integrator for marine applications, MAN ES is actively involved in exploring and developing new technologies for decarbonization.

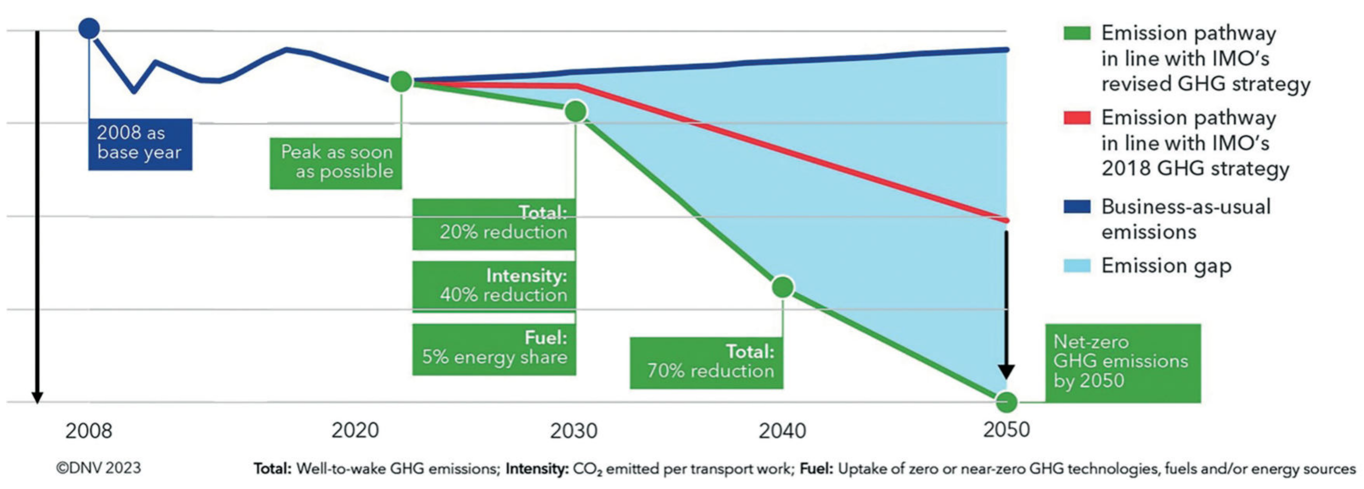


Figure 1: Overview of the reduction of GHG emissions in line with IMO´s strategy.

One of the main goals of the NAUTILUS project is to design and construct a hybrid modular demonstrator incorporating solid oxide fuel cells (SOFC) and batteries. This dual-system approach allows customization to meet ship operators' needs (e.g., base load vs dynamic load). MAN ES was responsible for designing, commissioning, and installing a 20 kW container at the German Aerospace Center, which includes a battery system, power electronics, and a main controller.

Genset Demonstrator

The 20-feet MAN ES battery and main controller container (marked with green colour lines) is part of the demonstration site at German Aerospace Center (DLR) premises. The container is interconnected to the fuel cell system and its main scope is to operate in parallel to the grid and deliver power to the local DLR 400VAC grid.

Solution Design & Integration

The MAN ES battery and main controller container consists of a battery rack system, power electronics units for stabilisation of the DC busbar voltage level and a programmable logic controller, which constitutes the communication backbone of the container. Interconnection to other components is achieved via Ethernet connectivity. In terms of safety there are protective mechanisms such as a fire detection system, grid protection components and system monitoring that have been implemented. The last main component of the container is the Real-Time PC (RTPC) – in other words the energy management system (EMS) – which is responsible for power distribution calculation between the available hybrid power sources. Some of the main components of the container are depicted in Figure 2.

Figure 2: Battery system, power electronics units (two middle photos), EMS and the control cabinet incorporating the Human Machine Interface (HMI) of the MAN ES battery container (from left to right).

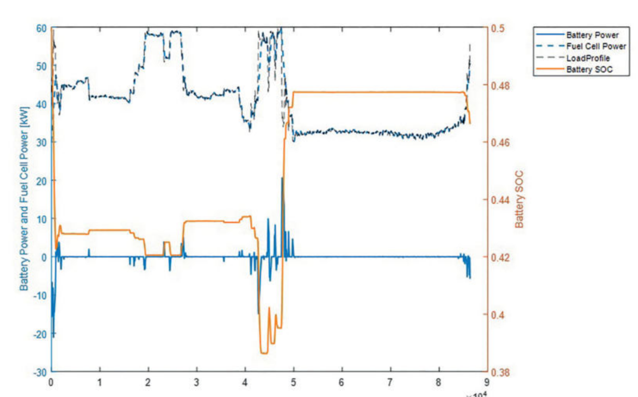
The low dynamic profile of the solid-oxide fuel cell (SOFC) system results in slow response to fast changes in the load rate. Therefore, the SOFC system covers low dynamic loads, while the battery system is responsible to cover high dynamic and transient loads (peak shaving). The functional demonstrator can operate in different operation modes such as manual operation (mainly used for bug-fixing and testing purposes), battery internal charging (direct battery charging from the SOFC) and EMS operation (parallel to the grid).

Calculation of the power distribution between the SOFC and the battery system is achieved based on different load distribution strategies at the RTPC that have been developed by the RWTH Aachen University. The EMS receives the total load demand profile by the container operator and defines the power setpoint values that should be sent to the corresponding hybrid power sources.

Results, Conclusions and Outlook

A testplan including different types of tests was implemented in order to test the specification range and boundary conditions of the modularised functional demonstrator. Static tests with constant partial and full power provision from the SOFCs, charging and discharging of the battery, as well as dynamic tests with a variable power ramp rate are performed. Tests simulating the operating modes of a ship (e.g. harbor stay, manouvering and coastal voyage) are implemented in order to control how the functional demonstrator deals with real ship profiles. Finally some edge case tests will be carried out, performing specification limiting cases for the SOFC, such as the load drop (to 0% power) or the load step (instant step from a power level to another one).

For almost all types of the aforementioned tests the CO_2 and non-CO_2 emissions will be measured in parallel, in order to illustrate the environmental footprint of the functional demonstrator operation.



In addition to measurements, simulations were performed to better understand the power demand distribution across the hybrid power sources. As shown in Figure 3, the SOFC (with a load change rate of 2%/min) is capable of closely following the load profile, while the battery system covers the high dynamic peaks.

Figure 3: Simulation of load distribution to the hybrid sources based on a real cruise ship profile

Contact Information

NAUTILUS

- **WWW.NAUTILUS-PROJECT.EU**
- info@nautilus-project.eu
- linkedin.com/company/NautilusEU
- twitter.com/NautilusEU
- #NAUTILUS_2020

MAN Energy Solutions

Fabian Grimm
Stadtbachstrasse 1, 86153 Augsburg Germany
Tel: +49 821 322 6460
Email: fabian.grimm@man-es.com
Web: MAN Energy Solutions (man-es.com)

Acknowledgement and Disclaimer

This work has been performed under the project NAUTILUS and received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 861647. This poster reflects only the author's view and the European Climate, Infrastructure and Environment Executive Agency (CINEA) and the European Commission are not responsible for any use that may be made of the information it contains.