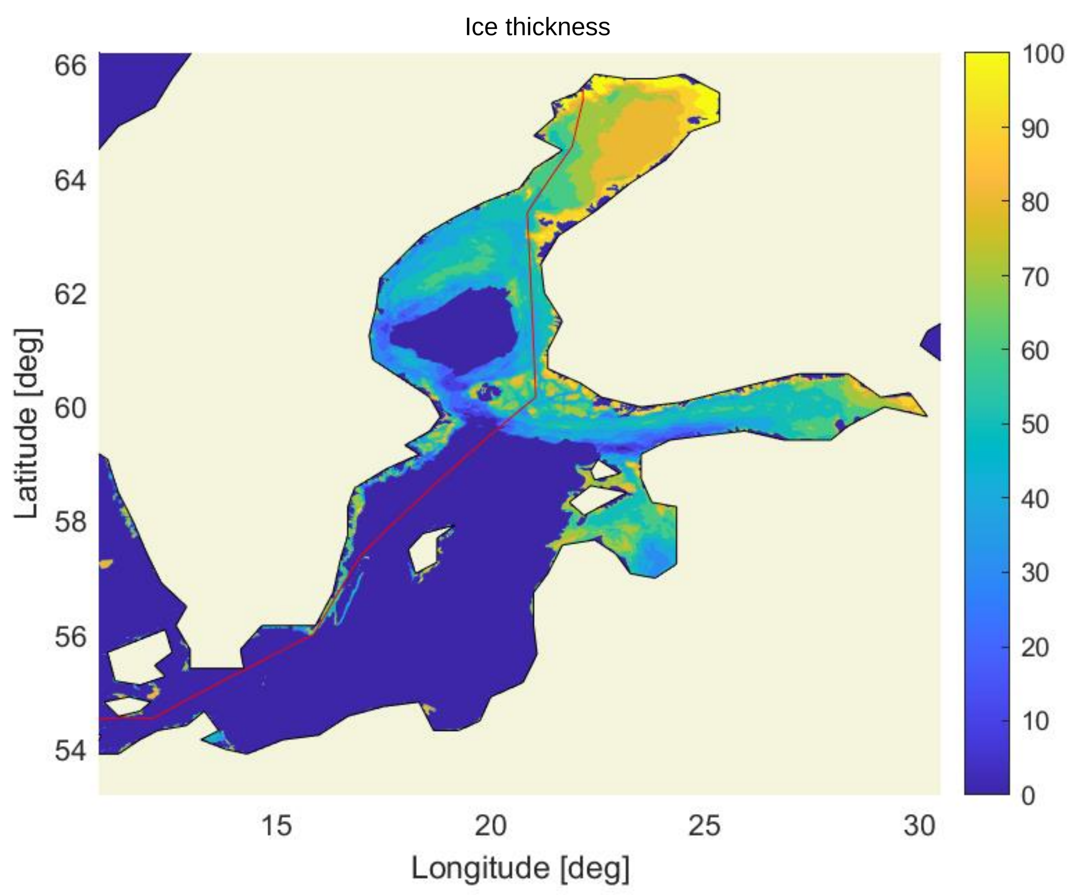
Hybrid energy system design study for a research vessel with ice class 1A

Tobias Lampe[1], Dheeraj Gosala[1], Gesa Ziemer*[1],

[1]Deutsches Zentrum für Luft- und Raumfahrt
(German Aerospace Center, DLR)
Institute of Maritime Energy Systems
*gesa.ziemer@dlr.de



The conceptualized research vessel for maritime energy systems developed by DLR is used as subject for the demonstration case. It will occasionally operate in ice, e.g. along an exemplary route from Kiel, Germany to Lulea, Sweden. Typical ice conditions on this route are derived from Weibull fit Copernicus data.

Challenges in the design of efficient energy systems for ice class vessels can be met with hybrid, modularized solutions.

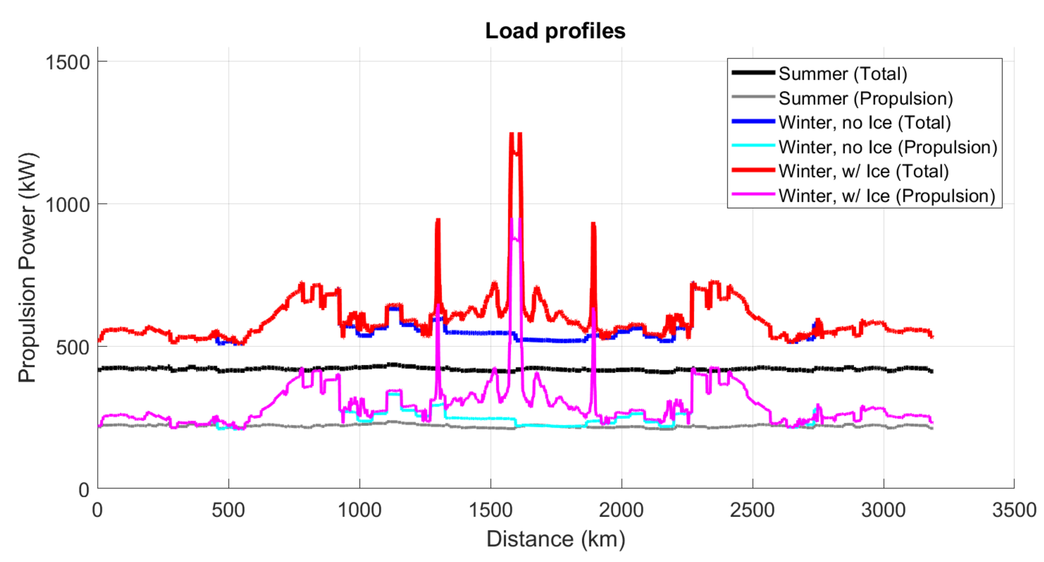
Ice class notations are typically applied to vessels which operate in icy waters only occasionally. The rules prescribe a minimum installed power which the vessel has to be able to provide regardless of actually required power, i.e. also in open water conditions. If the energy system of the vessel comprises of a diesel engine only, this means that it does not operate in the most efficient condition in open water due to the typical decrease of diesel engine efficiency at decreasing engine load. Hence, ice class certification can entail losses in efficiency in year-round operation.
Hybridization and modularization is a key approach to improve the overall efficiency of an ice class vessel, which is shown in this study using a 50m research vessel.

Methodology.
The proposed methodology consists of the following steps:

1. Calculation of vessel power demand for various environmental conditions
2. Route simulation to obtain ship-specific time- and distance based power demand profiles
3. Analysis of results from optimization-based energy management algorithm to identify most efficient energy system design based on Dynamic Programming

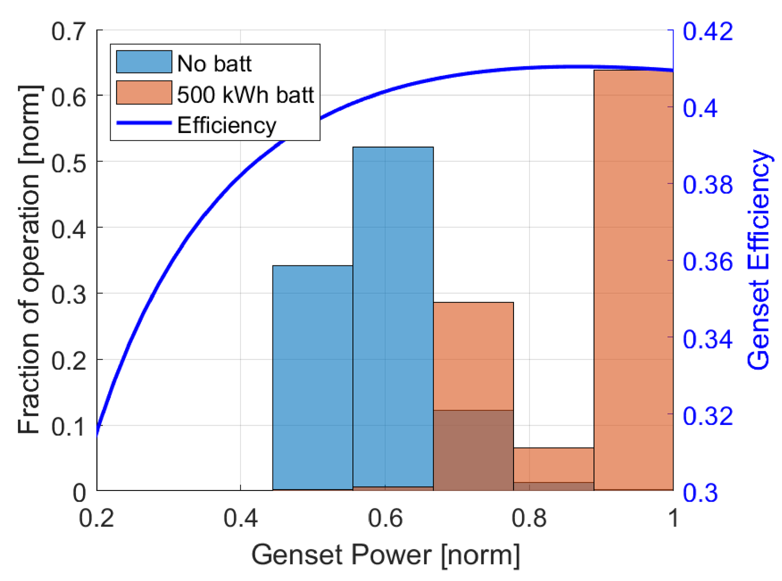
The algorithm minimizes the total energy consumption over the power demand profile while ensuring that the power produced by all considered components (gensets, batteries) lies within their respective power and energy limits. Efficiency curves for gensets and batteries are taken into account to obtain the energy consumption at given operation points. The battery is operated in „charge sustaining“ mode, preventing the need for shore-based charging.

Demonstration case.
The conceptualized research vessel of DLR with ice class 1A (FSICR) serves as demonstration case for this study. Calm water and added resistance are calculated based on state-of-the-art methods. For a conservative and simplified approach, ice loads are calculated based on Lindqvist and Colbourne methods for level ice and broken ice, respectively. Further information is given by Gosala et al. (2024).

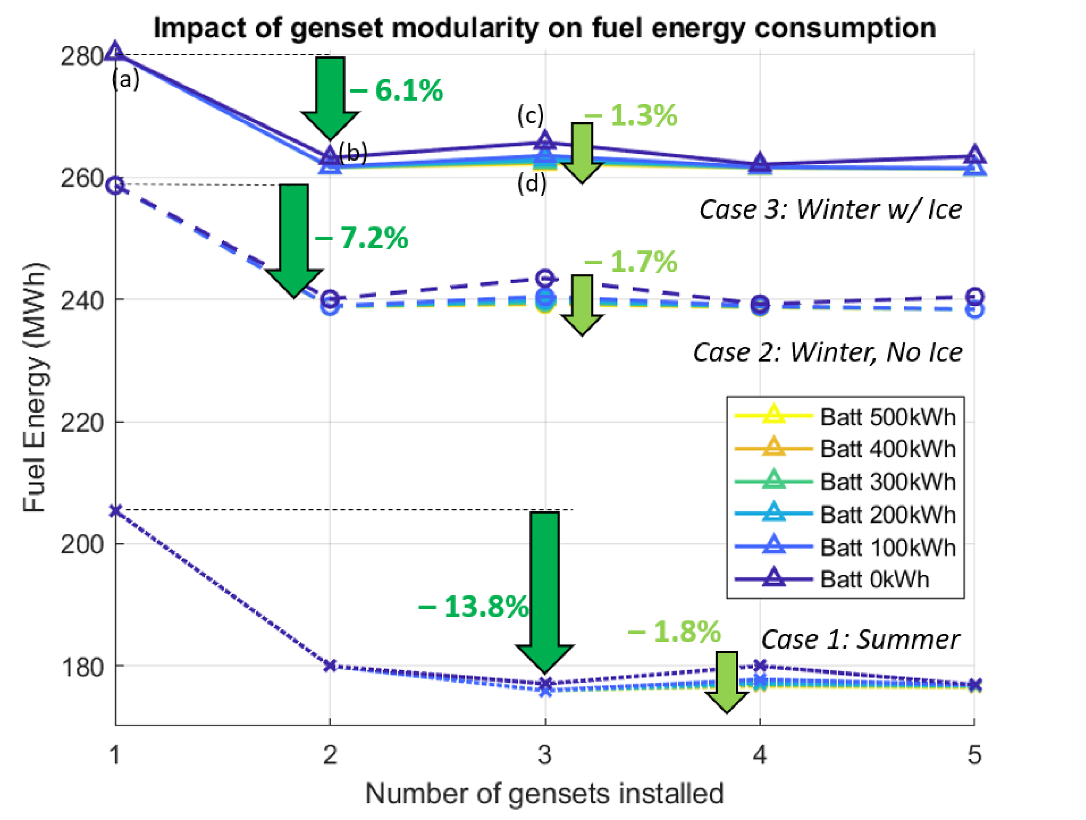


Power demands for the voyage between Kiel and Lulea highly deviate between summer and winter condition. Power demand in thin level ice exceeds the maximum open water power demand significantly.

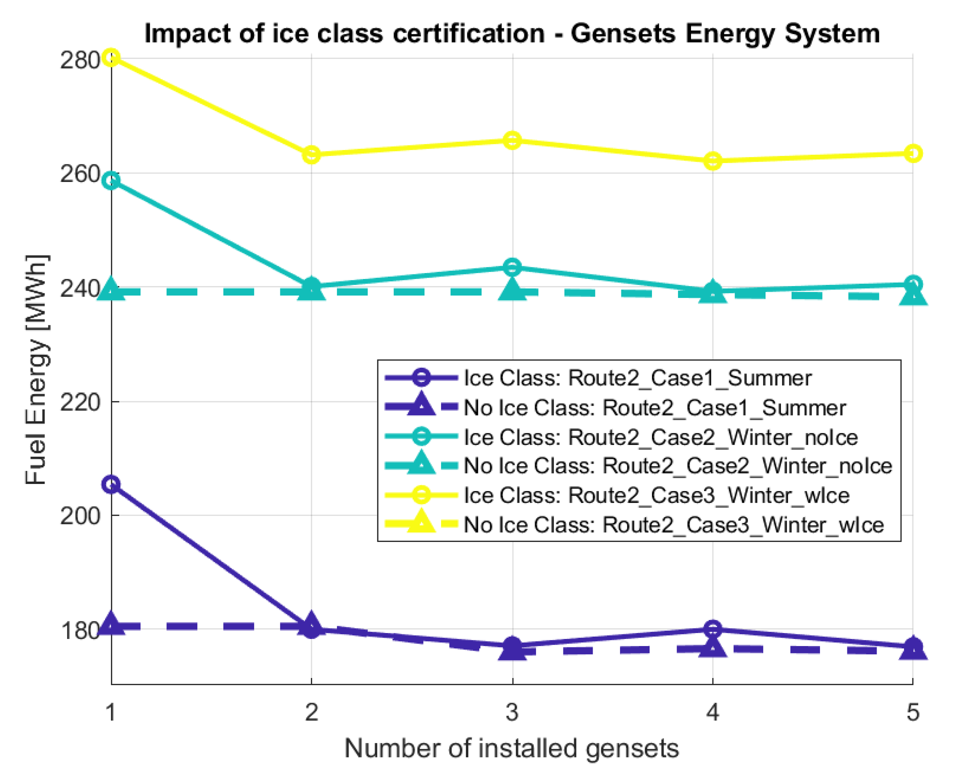
Results.
The optimization algorithm provides optimal operation strategies for various energy system designs. Comparison underlines the merit of hybridization and modularization of the genset system. Batteries can additionally aid to operate the gensets in more efficient conditions.



Use of batteries shifts operation points during winter voyage with ice conditions to higher efficiencies



Hybridization and modularization of the energy system increases the overall energy efficiency.



The efficiency increases significantly if the energy system of an ice class vessel is modularized.

Main conclusions and study outlook

- Modularizing diesel genset installations in an ice class vessel yields up to 13.8 % energy savings for the demonstration case
- Battery hybridization can compensate for non-optimal genset modularity
- Efficiency of an appropriately modularized ice class system can be as high as of a comparable down-sized energy system without ice class
- Further energy system components will be included in future studies
- Prediction method for ice loads will be enhanced to also include load variability and peaks

Further information

Gosala, D., Lampe, T., Ziemer, G., Ehlers, S. (2024). Design and Optimization of a hybrid energy system for an ice-class research vessel. Proceedings of the ASME 2025 44th International Conference on Ocean, Offshore and Arctic Engineering, Vancouver, Canada. DOI: TBC

Bundesministerium für Wirtschaft und Klimaschutz
DLR