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Energy efficiency Optimization for Ice-going ship operations: A focus on optimal power management strategies for Battery electric RoPax ships.

The shipping industry is currently experiencing a transformative shift towards greener and more sustainable transportation solutions with the aim of mitigating both human and environmental impacts as well as complying with stringent emissions regulations (Johnsson et al., 2020). The development of electric propulsion systems offers a great opportunity for the shipping industry to achieve its emission goals especially as it relates to Roll-on/Roll-off passenger (RoPax) ships that operates within the Baltic region (Kolodziejski et al., 2023). The deployment of these battery electric Roll-on/Roll-off passenger ships presents an opportunity to significantly reduce emissions, lower operational costs, and enhance the overall sustainability of the Baltic Sea transportation (Gray et al., 2021).

However, the efficient management of power distribution within electric RoPax ships remains a complex challenge that requires further research. This is because of the dynamic interplay between power demand, energy storage capacity, and operational profiles in an electric RoPax ship which presents a multifaceted problem that requires innovative solutions. Passenger ferries operating within the Baltic Sea often navigate through varying routes, encounter different operational scenarios like navigating ice-infested water, and react to fluctuating passenger demands, therefore the development of optimal power management strategies becomes fundamental to ensure optimal performance, maintain passenger comfort, and maximize energy efficiency (Geertsma et al., 2023).

The fundamental issue lies in designing and implementing power management systems that can dynamically allocate power across propulsion and auxiliary systems while considering operational profiles such as route characteristics, speed, distance, ice conditions, environmental, and peak power demands during maneuvers and port operations. Achieving the right balance between minimizing energy consumption and meeting operational requirements is a complex optimization challenge that requires a comprehensive understanding of electric ship systems, advanced control algorithms, and the interplay of various operational variables. To address this challenge, machine learning techniques, hybrid Particle Swarm Optimization (PSO) and Fuzzy Logic Expert system will be employed to optimize power distribution for enhanced energy efficiency and operational performance.

In thoroughly addressing the research objectives, this research would contribute to the Baltic maritime industry's shift towards cleaner and more sustainable transportation solutions, while also offering insights that can potentially extend to other electric vessel types beyond RoPax ships that navigate through open sea and ice-infested water.

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