PROPULSION SYSTEMS AND FUEL SUPPLY INFRASTRUCTURE FOR ZERO-EMISSION COASTAL FISHING VESSELS

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ABSTRACT

Fisheries and aquaculture combined is the 4th largest industry in Norway. The fleet consists of more than 6000 vessels of varying sizes. Annually, these vessels consume 24 % of Norway's total petroleum usage, and emits 1.5 Mt CO_2 equivalents[1]. Conversion to zero-emission energy carriers onboard requires a significant number of retrofit and newbuild vessels to reach the emission reduction targets for the industry. Demand is dispersed and irregular and requires a new approach to determine supply infrastructure.

Fishing vessels with battery-electric and hydrogen-electric propulsion systems are under development. Both batteries and hydrogen have lower volumetric energy densities than conventional fuels. As the size of fishing vessels in the coastal fleet are regulated by the Individual Vessel Quota System, a challenge is to fit sufficient energy storage onboard. In addition, fishing vessels have a highly varying operational pattern in terms of length of a fishing trip, location, and energy gear use. Passive gear and near port fishing requires 4-500 kWh energy, while using active gears like seines and trawls requires 800-1.200 kWh for a one-day operation.

In this R&D project a hydrogen-electric fishing vessel is currently being built; equipped with a 100 kW fuel cell and 32 kg hydrogen tank providing about 400 kWh. In addition, a 360 kWh battery will support the fuel cell and a diesel generator will act as back-up if the hydrogen infrastructure is not yet present where the vessel operates.

The energy need is a vital parameter for dimensioning energy storage, but also the required energy infrastructure for recharging and refueling of hydrogen. It is clear from public reports that there is a wide scatter in the estimated energy need for a fishing vessel[2,3]. To improve the understanding of the operational energy and power use of a zero-emission fishing vessel, the load profile of a battery-diesel hybrid fishing vessel has been logged and analysed. This information was also used to provide for the design and sizing of the onboard hydrogen and battery systems of the hydrogen-hybrid vessel currently being built.

Onboard measurements provide accurate information for the specific vessel. A fleet level analysis is necessary to better understand the variance in energy storage needs, localization, and

dimensioning of refueling and recharging infrastructure. In this work we develop a model-based approach and derive power and energy needs from vessel drag and speed over ground from AIS. Vessel drag is estimated using vessel dimensions and empirical and analytical correlations for fishing vessel drag. Methods for identification of fishing, steaming and waiting periods were identified, to enable addition of additional energy/power consumption during fishing. The energy efficiency as a function of engine load factor was approximated with a 2^{nd} order polynomial fitted to information of specific fuel consumption from literature. Finally, the method was validated against data from the Guarantee Fund for Fishermen. The method enables estimation of the spatial and temporal power demand at sea from the fishing fleet for infrastructure planning, and further analysis of variability of energy needs for fishing vessels.

Hydrogen bunkering infrastructure is not yet available in the relevant harbours. Localization and optimal dimensioning of the hydrogen bunkering station components will depend on the specific factors bunkering frequency, pressure level and thermal conductivity of the fishing vessel tanks and required bunkering rates. With use of pressure difference as the driving force for bunkering, a model for dynamic simulations of bunkering of several fishing vessels in series have been developed. The model was used to investigate the necessary hydrogen amount in the storage system at the station, with and without available compressors between low and high pressure tanks. Omitting a compressor reduces the need for maintenance, which may be beneficial for fuelling stations with low utilisation, such as fuel islands and off-grid refuelling stations.

Green hydrogen is produced by electrolysis and transported to bunkering stations by truck or ship. It can be beneficial to reduce transport costs by implementing distributed production. However, this cost-saving approach needs to be balanced against the more efficient production and lower costs of larger electrolysers. The electrolysers are assumed grid-connected and may be exposed to time-varying electricity and power tariffs. Additionally, they produce surplus heat and oxygen that can be sold for commercial value. Using the JuMP modelling framework in Julia, these aspects are integrated into one optimization model. The model can be used to examine the benefits of local production vs. more centralized production under various demand scenarios for hydrogen.

A successful transition to zero-emission fishing vessels requires appropriate scaling and optimal locating of hydrogen production and bunkering. Further work will therefore include combining these models and analysis tools to obtain an overall picture of the value chain. Altogether, these methods can be used to elucidate supply strategies based on novel refueling infrastructures such as fuel islands and off-grid refueling stations.

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