Battery hybrid applied to marine propulsion

The maritime industry is currently experiencing a significant increase of interest in battery hybrid installations for new buildings and retrofits. The driving forces include the current development in battery technology, potential for lowering operational costs, increased capacity of drivetrain and reduction of greenhouse gas emissions. Battery and hybrid propulsion have been suitable for some routes for a long time. Yet for a number of applications, other propulsion systems offer better possibilities for obtaining current design objectives, e.g. the correct capacity of drivetrain and reduction of greenhouse gas emissions. One of the crucial aspects is finding out when battery and hybrid propulsion is a feasible way of meeting the targets for a specific ship, including its operational profile. A number of recent projects show that SSPA has the tools and knowledge to answer these questions and to evaluate different alternatives for propulsion, from batteries and fuel tanks to propellers.

At SSPA, increased activity within the area of battery and hybrid propulsion can be seen in an increasing number of projects within this area. One example is the fast, air-supported commuter ferry "Airi El" in the project BB GREEN. Photo: Anders Mikaelsson, SSPA.

Increased interest in battery and hybrid propulsion

Battery applications have recently become interesting in relation to some large-scale marine applications. This is due to a combination of factors such as development within the field of lithium-ion batteries, giving improved capacity, reliability and reduced battery prices. Aside from technical factors, concurrent development can be noted regarding uncertainties in relation to future fuel costs and fuel supply, stricter emission legislation and greater environmental ambitions.

At SSPA, increased activity within the area of battery and hybrid propulsion can be seen in an increasing number of projects within this area. Examples include "Greener yellow ferries", a project for the Swedish Transport Agency involving environmentally friendly road ferries, described in an earlier issue of Highlights (62/2016), as well as technical project support for battery-powered sightseeing boats on behalf of ship-owner Strömma Kanal and the fast, air-supported commuter ferry "Airi El" in the project BB GREEN.

In the following, a couple of other projects from SSPA's project portfolio within the relevant area are summarised to give examples of how SSPA's tools and knowledge can be utilised to choose from a number of drivetrains.

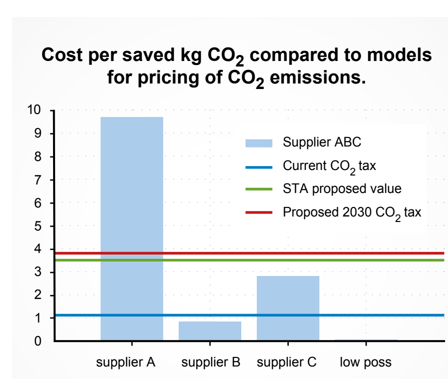
Hybrid work boat

SSPA was appointed early in the project to conduct the technical and economic feasibility study for designing a vessel with battery hybrid propulsion. The study also involved the conceptual design of drivetrains suitable for the ship's operational profile.

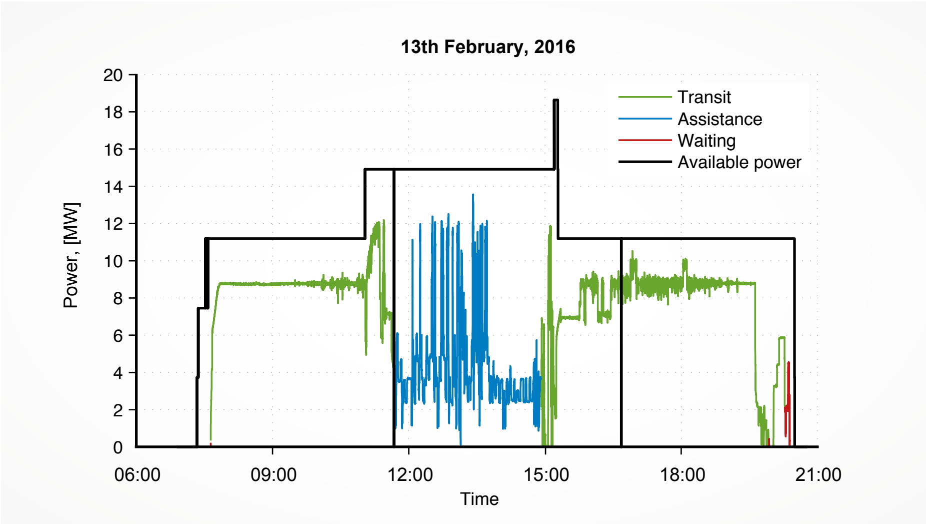
The work group consisted of a small team utilising expertise within Ship Design, Internal Combustion Engines, Life Cycle Cost Calculation, Operational Cycle Emissions and On-board Systems. Significant activities in this project include:

- Inquiries and interviews with the shipowner and ship crew including data analysis to define an operational profile
- Definition of battery/drivetrain concepts suitable for the ship's operational profile
- Calculation of life cycle costs for the drivetrain (from diesel engine/batteries to propeller shaft)
- Reduction of emissions of GHG (Greenhouse gas), NO_X, HC
- Comparison of the different drivetrain concepts with regard to cost, emissions, functionality
- Optimisation with respect to the operational profile of significant aspects of the ship such as main dimensions, drivetrain type, size of battery bank, type of battery chemistry.

Before the basis for the specification was established, a number of intermediate results were put forward to facilitate balancing of the shipowner's functional requirements. One such result is shown in the figure below. This figure shows the cost per saved kg CO_2 for different hybrid drivetrain concepts. The base value (zero cost/kg



Different drivetrain concepts and their cost per saved kg CO_2. Illustration: SSPA.



The figure shows total propulsion power along with the available power for an icebreaker during a typical icebreaking mission. Illustration: SSPA.

CO_2) represents a traditional diesel powertrain. The costs for the different hybrid drivetrain concepts were obtained by comparing different system solutions from different suppliers (denoted “supplier A–C”).

The alternative denoted “Lowest Poss” was built using compatible parts from the three suppliers, which resulted in lowest cost per saved kg CO_2. As a comparison and indication of what the permitted cost of CO_2 reduction might be, the horizontal bars in the figure show current and proposed future CO_2 tax in Sweden.

Such results were utilised in combination with functional requirements to balance requirements and costs.

Battery hybrid icebreakers

For vessels with dynamic positioning, battery hybrid installations have become a competitive alternative for new-builds as well as retrofits. High demands on system redundancy for dynamic positioning applications require multiple engines running.This results in low engine loads and many engine hours, hence less efficient operation and high maintenance costs. When such a system is fitted with a battery bank, the battery bank enables one or more engines to be switched off while redundancy demands are still fulfilled. This leads to increased efficiency for vessel operation.

A somewhat similar type of battery hybrid application has been identified for Swedish icebreakers. During assistance and towing in ice, icebreakers need a high power reserve to be able to maintain speed in case they hit an ice ridge or the ice gets thicker. The figure above illustrates this with an example of power demand and available engine power during an icebreaking operation. SSPA is conducting a study for the Swedish Maritime Administration to analyse the need for a battery hybrid installation, the feasibility and the life cycle cost. This project is planned to be completed later this year.

Hybrid drivetrain simulations

SSPA is continuously driving the development of simulation capabilities using a simulation tool for optimisation of hybrid propulsion, among other things.

The tool can be used to calculate the fuel consumption of a diesel-electric hybrid powertrain, an operational profile and drivetrain properties such as diesel engine start-up time. Another example of use is the design of optimal control algorithms for a diesel electric drivetrain with known start-up time for main engines for a given battery bank size.

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Since joining SSPA in 2016, Olov has been involved in projects in the areas of ship-motion simulations, battery hybrid propulsion, effect of ship propulsion on the seabed, propulsion machinery and marine operations. Prior to joining SSPA, he worked with subsea infrastructure for the oil and gas industry, engine development at Scania and marine operations at Westcon Group. He has a PhD within ship dynamics from Chalmers University of Technology and an MSc in Naval Architecture from the Royal Institute of Technology.

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Hamnfärjan I (1913) and Hamnfärjan II (1948)

There are examples of routes for which battery-powered ships have been suitable for a long time. One of these is the short route between the island of Koön and the island of Marstrand in Kungälv Municipality in Sweden.

The first electric ferry (Hamnfärjan I) on this route was delivered in July 1913. The second electric ferry on this route (Hamnfärjan II) was built in 1948 and had transported about 8 million passengers when it was decommissioned in 1985.

Today, this ship is operated as a historic vessel by a non-profit organisation. It has an 8hp ASEA motor powered by 40 battery cells of 2 volts each. The batteries are charged automatically on both stops of the route.

The electric ferry Hamnfärjan II (Courtesy of Färjans Vänner Marstrand).