
HOW TO DEVELOP A BATTERY-ELECTRIC PROPULSION CONCEPT FOR A VESSEL?

♦ A B S T R A C T ♦

Nowadays, maritime transport is experiencing the beginning of a transition towards less polluting propulsion systems, such as electricity, which can be obtained with the use of batteries. The following example presents, in summary, how a motorization could be developed under the concept of electric batteries for a zero GHG emission ship that makes short-distance trips with an electrical supply in port.

Keywords: Battery-electric, Propulsion, life cycle

¿CÓMO DESARROLLAR UN CONCEPTO DE PROPULSIÓN ELÉCTRICA A BATERIAS PARA UN BUQUE?

♦ R E S U M E N ♦

Hoy en día, el transporte marítimo está experimentando el inicio de una transición hacia sistemas de propulsión menos contaminantes, como la eléctrica, la que se puede obtener mediante baterías. El siguiente ejemplo describe resumidamente, cómo podría desarrollarse una motorización bajo el concepto de baterías eléctricas para un buque de cero emisiones de GEI que realice trayectos de corta distancia con el uso de suministro eléctrico cuando permanece en puerto.

Palabras clave: Eléctrico a batería, propulsión, ciclo de vida



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One of the most critical aspects that will be considered during the development of a ship design project is the definition of the propulsion system, which describes how the vessel complies with its mission according to the necessary requirements of the place where it will be commissioned. In this case, this project is focused on developing a passenger ferry capable of connecting countries via a sea strait of 4 nautical miles. Electric power from batteries will be used for power propulsion.

This report will detail the vessel requirements for the project, followed by the details of the project, which will include the specifications of the battery concept, such as charging information and sailing schedule. Then, the life-cycle assessment of the energy provided by the batteries will be described to finalize a comparison of this electric propulsion system with a conventional diesel propulsion system in terms of air pollution.

Vessel Requirements

To improve the understanding of the project, the following paragraph will be described the requirements for the design of the propulsion electric system of the vessels as follow:

- Distance to navigate: 4 Nautical miles (NM)
- Total distance to sail per day: 96 (NM)

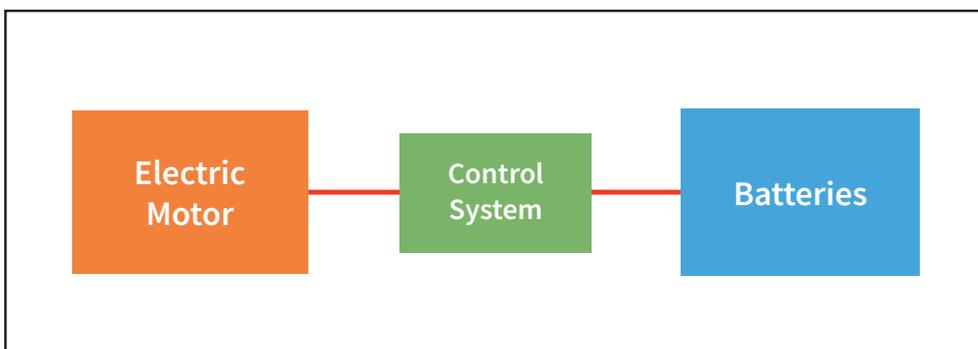
- Power propulsion required: 2 (MW)
- Type of power propulsion system: Electric power
- Type of batteries: Lithium-ion
- Sail speed: 10 Knots (Kts)
- Maximum distance with one charge: 64 (MN)

Details of the project

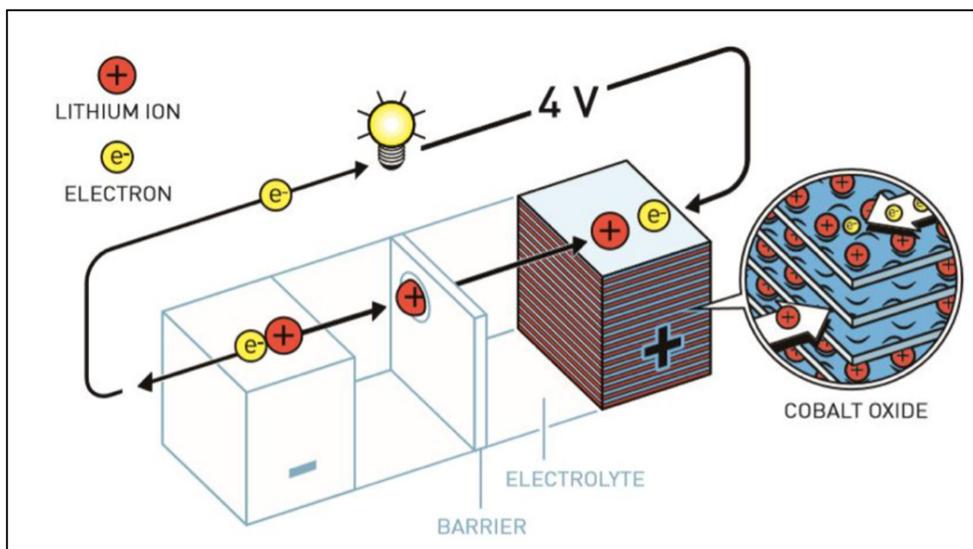
The details to accomplish the requirements for the vessel will be explained in the following subparagraph:

Battery-electric propulsion concept: The battery-electric propulsion concept of this project will include an electric motor controlled by an electric system connected to a rechargeable battery matrix. The propeller will be connected to the electric motor to control the range of the revolution and, consequently, the vessel's speed.

The rechargeable energy matrix will be composed of Lithium-ion batteries. Those batteries work by constantly trespassing electrons between poles through a barrier, and each cell is designed to produce a voltage of 4.2 (V) (TNP, 2019). The interaction between the cathode and anode took place inside the cell through a chemical reaction. The guaranteed lifespan of the batteries is five years.



Battery-electric propulsion concept, done by Author.



Lithium-ion battery concept, picture obtained fromm Nobel Prize homepage.

To produce sufficient energy, the vessel will store a matrix of batteries to provide the power required equivalent to 2 (MW). The aim is to sail at 10 (Kts) for the 4 (NM), the distance of the strait separating both ports.

The technical characteristics of the Lithium-ion battery that will be used for further analysis are the following (Schönborn, 2023):

- Energy density per volume: 200 (kWh/m³)
- Volumetric power density: 1500 (kW/m³)
- Gravimetric energy density: 200 (kWh/ton)

Another essential feature of the concept is the use of water-cooled batteries to protect the system from dangerous temperature changes, considering that this characteristic of batteries can jeopardize the system onboard.

With the results obtained, one 20 (ft) container had a cubic capacity of 33.2 m³; therefore, using only one container full of batteries (8 modules of 4 m³ every each) will be possible to keep sufficient energy for eight straight crosses without charging, in other words, this vessel will have available on board 12.8 (MWh) in each cross of the waterway. According to the requirement, the ship should cross the strait 24 times

daily. Consequently, the maximum distance with only one charge equals 64 (MN).

Nevertheless, it will install two containers on board to ensure electricity support.

Charging Concept: The charging concept will have two parts: one located in the vessel with a connection on each side of the hull (port and starboard) to facilitate connection while staying at berth, and the other part of the dock of every port.

The idea of this concept is to provide electricity for the ship during every berthing and, with this electricity, charge the batteries on board to keep sailing and support each other necessary services.

The system will be a fully automatic laser-controlled robot arm to improve accuracy, and every charge will provide 2 (MW), 3500 (V) and 600 (Amp) in 10 minutes of connection.

Using the total amount of batteries, in theory, it will not be necessary to recharge every time in port; nonetheless, as a ferry vessel and the relevant nature of cargo on board (people, cars and trucks) is necessary to ensure the safety onboard providing the total energy available permanently, for that



Charging connection, picture obtained from FORSEA homepage.

reason, the vessel will charge its batteries in every arrival at berth, filling its batteries matrix located inside of 2 containers of 20 (ft).

Sailing Schedule: According to the requirement, the vessel should cross the strait 24 times daily; thus, the sailing schedule will consider departure every hour, disposing of 24 chances to cross for passengers.

Energy backup: To ensure safety and environmental protection onboard, the

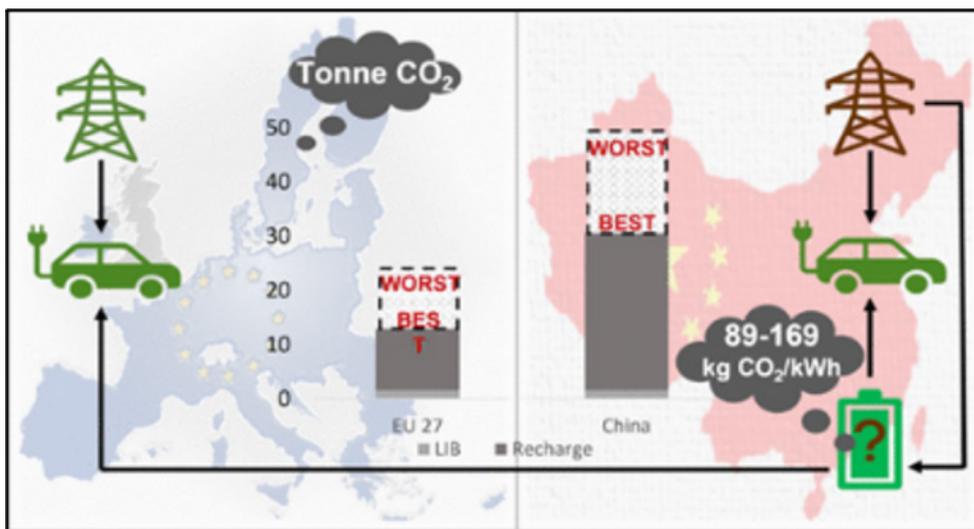
vessel has a diesel engine propulsion system inside that can be connected to the propeller in case of an emergency where batteries cannot provide enough power to move the ship. This allows the ship to arrive at any port without danger to the passengers. Nevertheless, this report will not further consider the diesel engine concept.

Life-cycle Assessment

Under the life-cycle perspective, this project has the main objective of reducing CO2 emissions by avoiding the use of fossil fuel oil for propulsion, making this project sustainable for the environment; for that reason, sounds logical to obtain the energy required from a renewable source such as wind, tidal, sun or whatever other that allow fulfilling this compromise. In this line, every port of call of this ferry will be supported by energy obtained from the tidal energy. At the same time, the tidal energy will be collected using a turbine farm concept, such as the project shown in part A of this report.

On the other hand, the life-cycle of lithium-ion batteries includes different phases, from the effects of the raw materials used for their manufacture to their final disposal. Every phase can produce pollution or

Departure Port A	Departure Port B
00:00	01:00
02:00	03:00
04:00	05:00
06:00	07:00
08:00	09:00
10:00	11:00
12:00	13:00
14:00	15:00
16:00	17:00
18:00	19:00
20:00	21:00
22:00	23:00



Lithium-ion battery LCA, picture obtained from Bonulami and Tabrizi (2022)

another problem (Arshad et al., 2022). Therefore, it should be overcome with an international standard that establishes the baseline of a framework to deal with and treat the waste appropriately generated.

One example of the potential impact of global warming on the production of lithium-ion batteries is the result shown by Bonulami and Tabrizi (2022). The findings indicate that the amount of CO₂ emissions in producing 1 (kWh) of battery energy storage can range from 8g to 16g (kg) CO₂ eq., depending on the source of lithium.

Defining an international standard for the life-cycle of lithium is becoming more critical because of the increasing use of lithium-ion batteries and their potential for future developments considering materials, locations and any other important factor that can change the LCA assessment.

Comparison with conventional diesel propulsion system

This project was developed in order to shift the energy propulsion system using electric energy stored in batteries with the principal aim of decarbonisation. If we

compare a conventional diesel energy propulsion system with the system analysed in this report, in a superficial examination, it is possible to note that an engine of 2 (MW) using 391.8 (L/h) of diesel oil (CF 3.206 t-CO₂/t-fuel) can produce in one hour 1.47 (tons) of CO₂ emissions. In contrast, the electric system shown in this project emitted practicable zero CO₂, accomplishing the objective proposed.

On the other hand, cost factors would be interesting to evaluate in further analysis to understand the benefits and negative financial aspects of similar decarbonisation projects for maritime transport.

Conclusions

To conclude, this report provides several aspects considered to develop a short-sea shipping concept ferry connecting two countries via a sea strait of 4 nautical miles distance using electricity storage in batteries to sail, providing 2 (MW) required for the propulsion system which includes an electric motor, control system and batteries. The battery matrix is composed of lithium-ion batteries of 4.2 (V) with a lifespan of 5 years. In addition, the vessel will have 12.8 (MWh) to cross the strait every time, thanks to two onboard containers containing the battery matrix.

The ship will be recharged on each arrival to the berth, where it will connect to an automatic laser-controlled robot arm to improve accuracy, and every charge will provide 2 (MW), 3500 (V) and 600 (Amp) in 10 minutes of connection with the idea to be totally charged always. The Ferry will sail 24 times a day, departing every 1 hour. Regarding the life-cycle assessment, it is clear that lithium-ion batteries need further

research, even though it is possible to understand their impact from the current information available.

Finally, this project complies intending to take advantage of decarbonising the environment because a conventional diesel propulsion system does not have a comparison with batteries in terms of emission into the air.



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