The Opportunity for Fuel Cell Use in Marine Vessels

by Paul Paterson

The ongoing electrification of vessels is an extremely important development for the maritime industry as we strive to meet tightening emissions goals and regulations. It is important that we understand the portfolio of options available to us for providing the energy that electric ships require.

For many applications, batteries can satisfy both the energy and power requirements of a vessel. Batteries are very efficient, powerful, simple to maintain, and easily scaled. However, the weakness of the battery lies in its energy density. Despite recent improvements, massive batteries are still required for applications requiring long operating time. These are applications where fuel cells provide an attractive alternative.

Fuel cell power plants are systems that electrochemically react fuel with air to produce electricity. If the fuel is hydrogen, the reaction produces only water as a by-product. Like combustion engines, one differentiating factor between fuel cell systems and batteries is that fuel cell systems specify their rated power and energy storage capacity independently; whereas with batteries, power and energy storage are both specified by the size of the battery. This leads to an advantage for fuel cells where the energy requirement is large but the power level is small.

For instance, if we compare a production marine battery energy storage system and a production 350 bar compressed hydrogen cylinder from leading manufacturers using their published specifications, it can be easily seen that hydrogen is a superior energy carrier. Hydrogen-based energy storage is much lighter, smaller, and less costly.

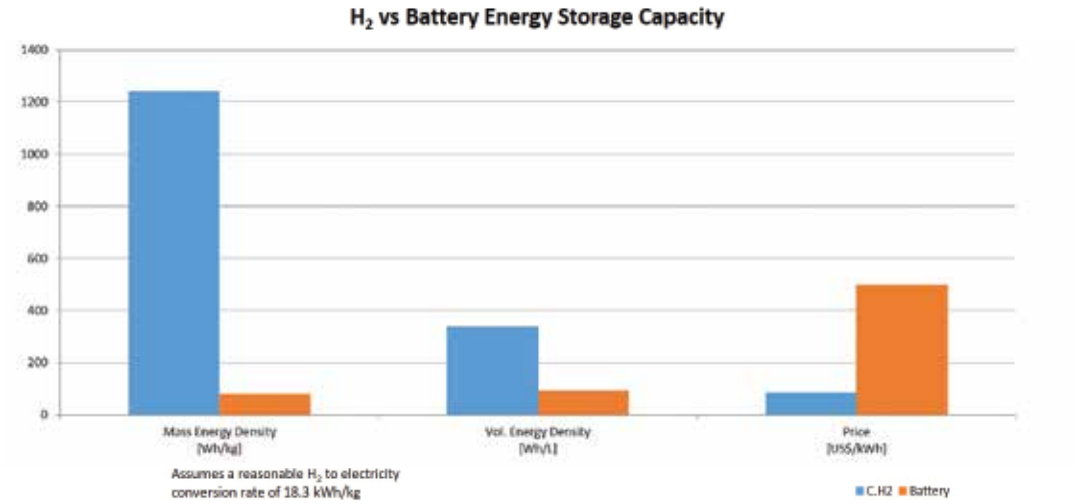
However, just comparing energy storage paints an incomplete picture as the fuel cell power plant must be considered in the scenario as well. These systems are rather expensive and heavy. Current fuel cell prices are trending downward from lofty origins toward CDN$1300/kW. Even so, this is still a high price to add onto the price of hydrogen storage.

Therefore, fuel cell systems really only make sense when power levels can be kept low in relation to energy requirements. In other words, if the average C-rate requirement of an application is under 0.5, a fuel cell option should be considered.

Hybridization of batteries and fuel cells together is a proven method to capture the benefits of both technologies. In applications such as short-run ferries with load cycles that include periods of both high and low load, a fuel cell could be sized to handle the average power requirement of the cycle while a battery supplements by handling peak power. The fuel cell recharges the battery during idle periods, and they work together to cover high load periods. Hybrid systems can be less expensive than either 100% battery or 100% fuel cell systems, depending on the nature of the load cycle.

Modern fuel cell systems are robust, and have demonstrated well over 25,000 hours of operation in strenuous transit bus applications. They can handle the high speed dynamics required for manoeuvring operations. Fuel cells also produce warm coolant that can be used for interior heating, which can otherwise be a significant energy consumer. At its core, a fuel cell system is still an electrical system, and the propulsion system in a vessel powered by a fuel cell would be very similar to that used in a battery electric drive.

Despite its benefits, hydrogen does have limitations. Firstly, it can be a very expensive fuel if produced from green electricity. Costs can



be lowered if produced from biogas, or when obtained as a by-product of industrial processes. The hydrogen energy cycle is also much less efficient than battery charging-discharging. The round trip efficiency of hydrogen is in the range of 30-35%, as compared to about 90% for batteries. Despite these limitations which increase the operating costs of a vessel, hydrogen may still find usage in applications requiring larger energy storage at low weight and size. This would be true for lightweight fast ferries that require considerable range, for instance.

For applications requiring longer range and even more energy, alternative solutions with higher energy density must be developed. One available solution is to switch from compressed hydrogen to liquid hydrogen. Viking Cruises is already working on a fuel cell cruise ship using liquid hydrogen storage. Other options under development that provide even more energy density are alternative hydrogen carriers such as methanol and ammonia. These liquids can be stored at low / no pressure and converted to hydrogen as needed for use in the fuel cell, while providing superior energy density and easier handling.

Fuel cells are a viable option today for zero emissions marine applications requiring better energy density than batteries can provide. There are a range of other advantages of fuel cells as well; for example, hydrogen can be filled more quickly than batteries can be recharged and there is no power degradation with the state of charge as can be expected when using batteries.

When hybridized with a battery, these benefits can be extended to a broader array of applications. As new technologies continue to improve in hydrogen production and storage, and as fuel cells continue to roll out in cars, buses and trains, we will continue to see improvements in price and efficiency. Concept vessels are currently being designed and ship designers are showing interest in the potential for fuel cells. Over the past decade, numerous R&D projects have been undertaken to demonstrate fuel cell power at sea, but commercial uptake had been slow. However, recently there have been several projects launched in Europe (Norway in particular) including foot ferries, Ro/Ro, Ro/Pax, cruise ship development, coastal shipping and even luxury yachts. The past and expected future success of these vessels clearly mean this is a technology to keep an eye on.

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