White paper: Hybrid propulsion technology

An optimal solution for meeting increased demands.

Reduce emissions and improve efficiency

Hybrid propulsion technology utilizes multiple power sources to produce energy and drive a vehicle. Ships predominantly use a diesel generator, a battery pack and an electrical propelled motor. However, other options are available for energy generation such as fuel cells, dual fuel combustion engines and solar cells. The objective is to reduce emissions and improve efficiency. An electrical solution will have a positive effect on vessel performance and manoeuvrability, as well as improve comfort for crew and passengers.

What are the advantages?

Hybrid technology is a viable solution for addressing increasing demands from governments, municipalities and authorities to protect urban and coastal areas from noise and pollution. For ferry operators in this segment, conventional propulsion technology is rarely an option to meet new regulations. However, rather than driving cost up, hybrid technology delivers a clear economic benefit through lower fuel consumption and improved equipment reliability.

Interestingly, there is a misconception about the economic benefits of hybrid technology. As a consequence of more components in the propulsion line (Figure 1), energy loss is greater and overall efficiency rate is lower in a hybrid and diesel electrical propulsion line compared to a conventional one.

Propulsion line energy losses

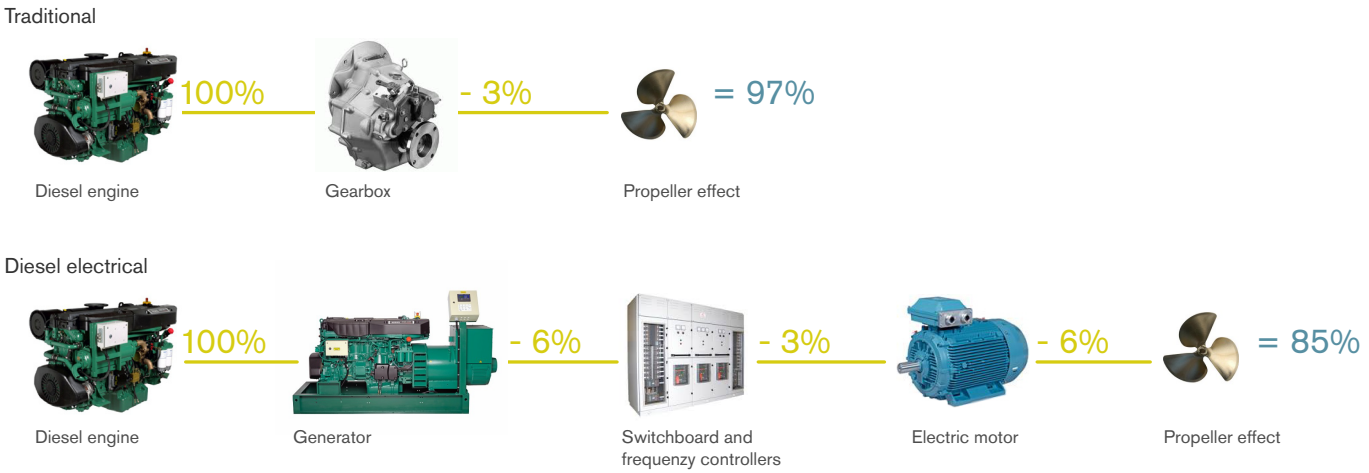

Figure 1. Comparison of energy loss

However, when analysing the operational profile of a vessel, particularly ones running short trips between ports in urban, coastal and inland waterways, it is apparent that these run very seldom at the optimal load due to the many stops and speed restrictions along their route.

While a diesel engine requires 80-90% load to be efficient, the average load is typically10-20% of the installed power. A hybrid solution with a larger number of small diesel generators, together with a battery pack, increases operational efficiency by delivering the appropriate power for different operational profiles. In addition, the battery pack gives instant power, otherwise known as a “peak shaver” without a delay. This feature is used for starting and synchronizing an additional diesel generator when needed for manoeuvring or even running a windlass or deck crane.

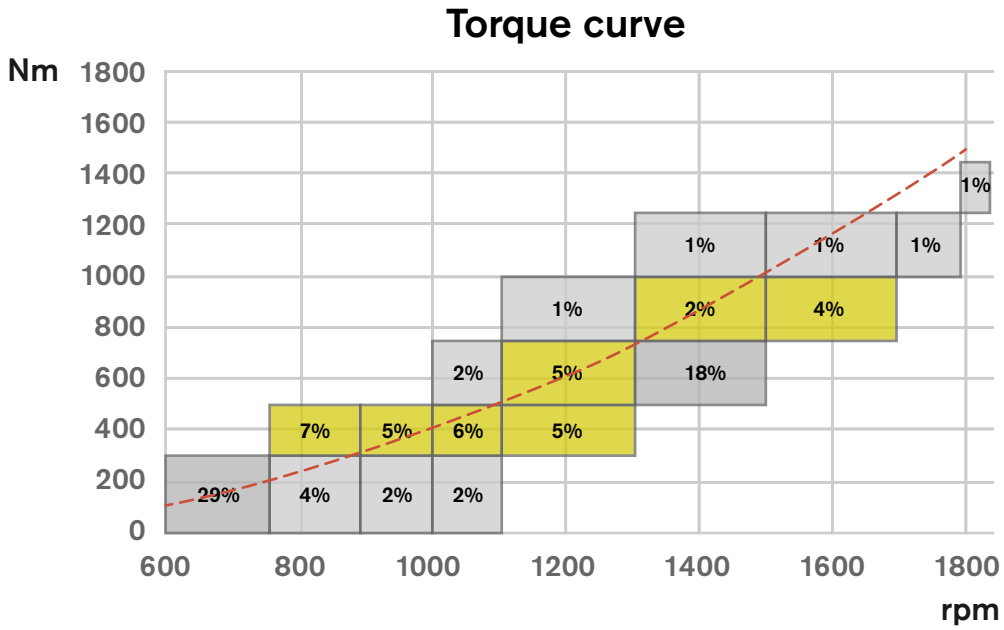

Figure 2. Operational profile for a small coastal passenger ferry, showing various load and rpm running times.

Another factor contributing to lower fuel costs is the efficient and balanced arrangement of the main components in the vessel engine room. For example, diesel engines do not have to be connected to a propeller shaft and battery packs can be split and distributed to replace ballast.

Electrical and hybrid solutions require a higher investment costs, caused by more expensive equipment than a conventional propulsion line. However, under the right circumstances, the reduced fuel and maintenance cost typically delivers a return of investment (ROI) in 5-10 years. A recent study conducted by Bellona institute and Siemens endorses this ROI calculation. The analysis predicted significant benefits for over 70% of coastal road ferries in the Norwegian Fjords if they are converted from conventional to either Hybrid or Battery powered propulsion. In addition to an ROI of less than 5 years, CO2 emissions would be reduced by 300,000 tonnes per annum (equivalent to the emissions from 150,000 cars).

Increased technical feasibility

Electrical drive technology has been around for a century and Callenberg Technology Group has been working with electrical and hybrid propulsion systems for more than two decades. The development of more reliable and cost efficient commercial off the shelf (COTS) components, offer

new opportunities to meet today's environmental requirements compared to 10 years ago. Batteries offer higher capacity with lower prices and less weight, electric drives are less space consuming and in general, component reliability has increased. The most common kind of battery in a hybrid propulsion line is lithium-ion. This is the same type used in today's cell phones. Providing the same benefits, small size, low maintenance cost and less environmental impact compared to other types such as nickel-cadmium.

What are the key success factors?

In this typically conservative industry, there is often a natural resistance to introducing new technology particularly for operation-critical systems. Electrical and hybrid technology has now been proven in land and marine operations and there are no documented cases where malfunction has led to significant safety or operational impact. Instead, it is in the design stage and system integration where the pitfalls come. Finding the right configuration and dimensioning of diesel generators, batteries, battery chargers and shore connection is essential for an efficient operation. A hybrid propulsion system consists of many parts, which must work well together with streamlined design, simplicity and user friendliness.More importantly, selecting reliable components from well-known and recognized suppliers is a key success factor.

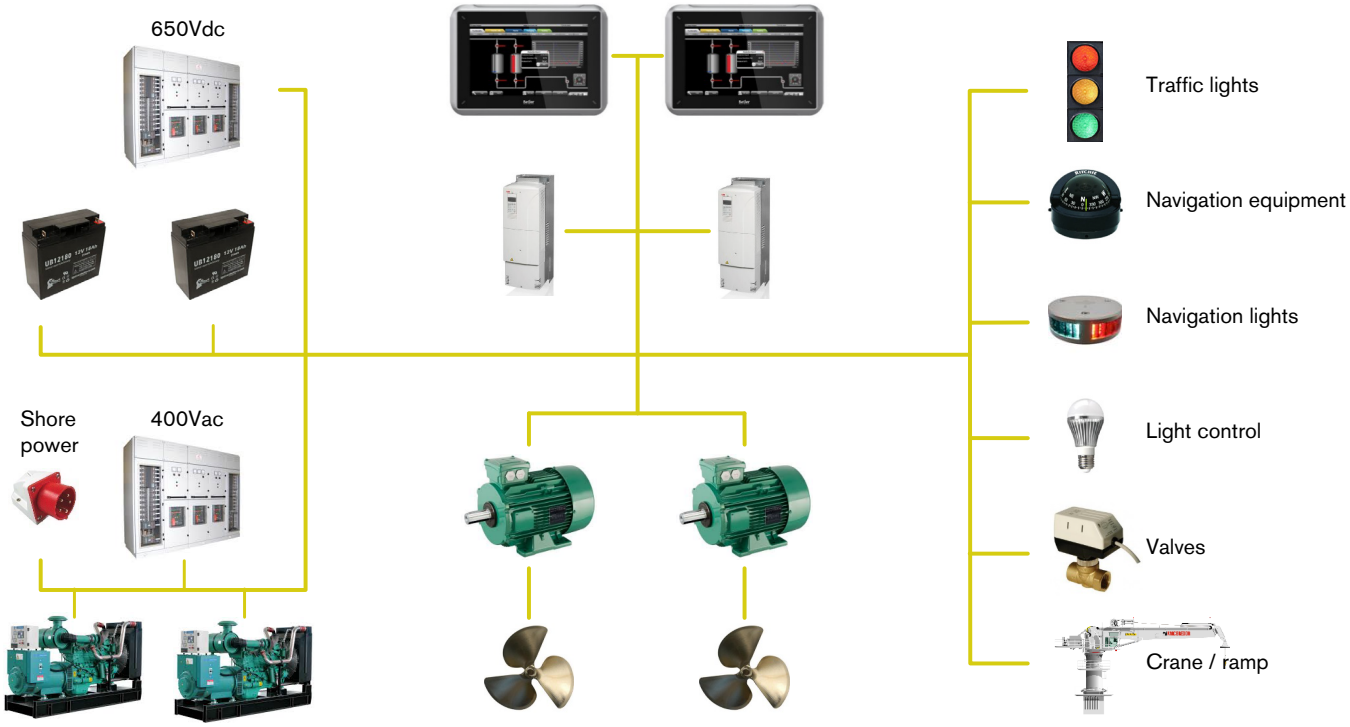

Figure 3. An integrated solution for propulsion, power distribution and automation

One of the major operational challenges, especially when batteries are the main energy source, is a quick and reliable electrical shore-connection for charging. The demands are high with an instant connection to charge in a few minutes. Shore connection has been and is still a challenge when designing the system, both mechanical and electrical. Today's options are mechanical connections of power plugs or inductive charging. With inductive charging, the process of connecting a vehicle to a shore based power source is substantially simplified. However, this technology still needs development, and is especially challenging for ships operating in high wind, current and swell.

Electrical harmonic distortions have always been an issue with solutions involving large electrical drives. This distortion affects other electrical equipment and can cause serious malfunctions. For the system integrator it is essential to ensure that the design and installation is carried out correctly and EMC (electromagnetic compatibility) compliance is verified before and after installation. One of the main rationales of investing in a hybrid propulsion line is to reduce fuel and energy consumption. Therefor it is important to measure, compare and analyse the consumption in operational conditions. Automation and HMI (human-machine interface) that are a part of monitoring and controlling the propulsion plant can be equipped with “economiser” software for recording the necessary energy consumption parameters. Results are stored and retrieved later for benchmarking. For a vessel running on standard routes, this is a powerful tool to improve operational efficiency.

How can we help?

Callenberg Technology Group has been working with diesel electrical, hybrid and battery powered ships for over two decades. Our focus is finding the optimal solution for each operator and route based on the actual route requirements, timetables, vessel design and of course requirements from authorities and societies.

We know where the challenges and the pit falls are and can avoid this at an early stage. Callenberg supports the whole life span of the vessel from design to operation.

Figure 4. Battery powered commuter ferry M/V Sjövägen, winner of the Stockholm city environmental prize in 2015, which is equipped with propulsion technology from Callenberg.

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