Door Ing. P.J. Sebrechts

Green Solution for World's First Seagoing Hybrid Ferry

Scottish company Caledonian Maritime Assets Limited (CMAL) aims to provide efficient, cost effective and safe ferries, harbours and port infrastructure for operators, communities and users in and around Scotland. With this in mind, the idea of a hybrid ferry arose and in cooperation with Imtech Marine, CMAL started developing a ferry that could fulfil these goals.

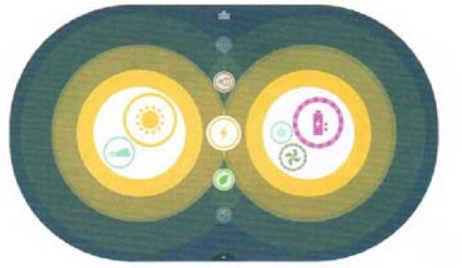
The new ferry should reduce CO, emissions by fuel saving and, therefore, alternative energy sources were considered. The company found a partner in Imtech Marine to help solve the problems they would come across.
Imtech Marine holds a vision of a future where ships worldwide sail without producing emissions and leave no environmental effects behind in their natural surroundings. The company has a lot of experience with diesel electric propulsion and environmentally friendly solutions, focusing on developing power systems that are more energy efficient and, by optimising energy use, result in less fuel consumption or even involving no fossil fuels at all. Together, the companies developed two seagoing hybrid ferries. Bringing a world first to the maritime industry is a challenge and hard work. When the first hybrid ferries are fully operational, the project, from idea to reality, will have taken around eighteen months.

Routes and pons in Scotland

The world's first seagoing hybrid ferry Hallaig

The ferries, also described as the "lifeline" for many islanders, will be operated by Clyde and Hebrides Ferry Services' CalMac Ferries,
and will be designed for the many short routes around the Clyde and Hebrides. With a service speed of nine knots, the hybrid ferries will be able to accommodate 150 passengers, 23 cars or two Heavy Goods Vehicles (HGVs).

The Energy Mixer
CMAL's ambitious ideas inspired Imtech to create a new automation system that controls the power sources in the most efficient way,

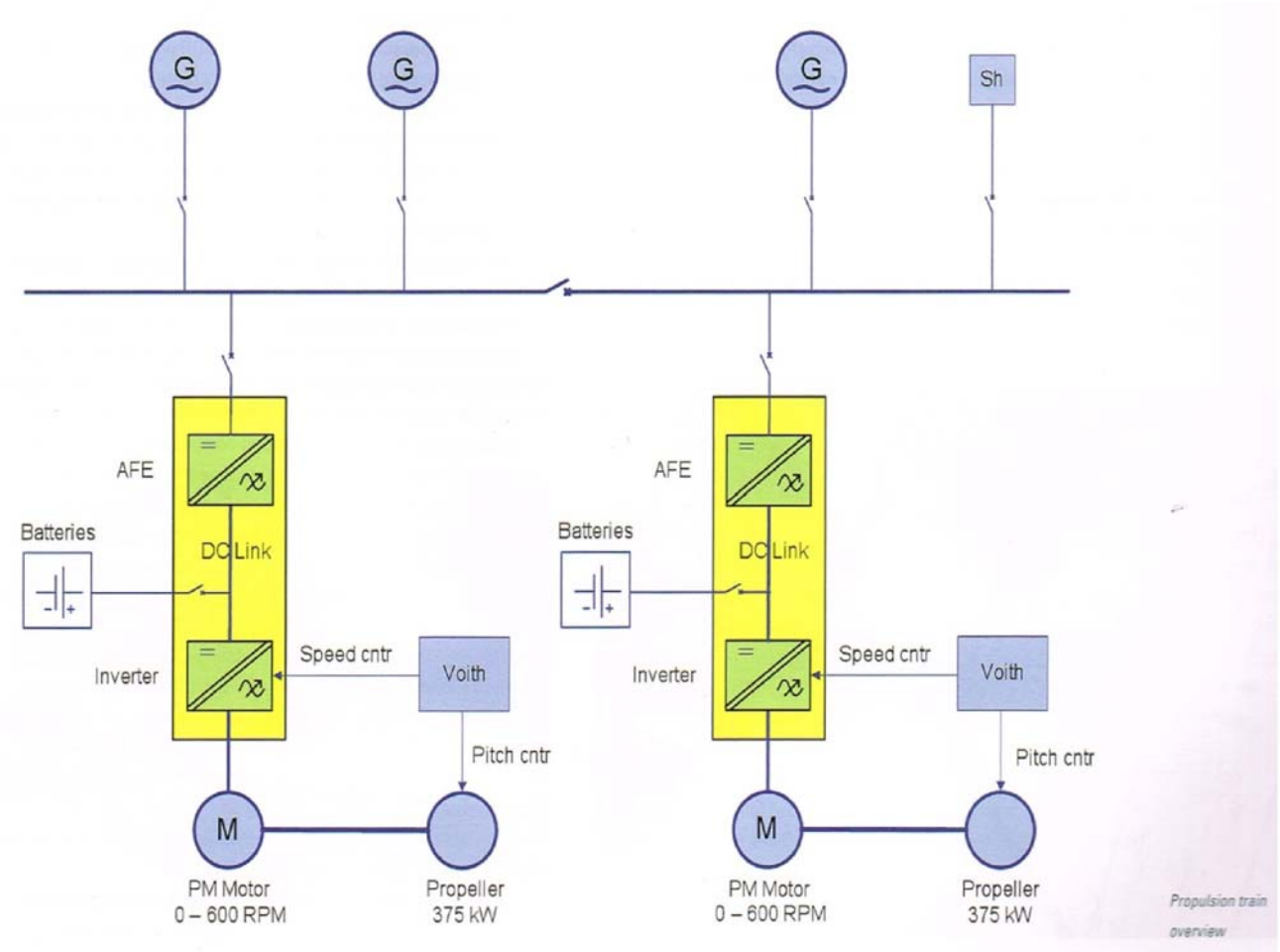


Controlling power sources with the Energy Mixer

together with a user-friendly human interface. Nowadays, a variety of power sources are available on board, including diesel electric, LNG, fuel cells, solar cells and wind energy, in combination with batteries, and further developments will no doubt continue in the future. Imtech Marine believes this variety of sources can run optimally in combination with batteries. It is very complex for the operator to manually control this range of power sources in an optimal way, noting that this "optimal way" might also be changing regularly and at an instant. Furthermore, operators should be able to focus on their core activities, which are not usually directly associated with managing various available energy sources.

The recently developed Energy Management System, known as the Imtech Marine Energy Mixer makes it possible to make the optimal combination of the various types of power sources on board, taking specific customer goals into account. The Energy Mixer is tuned to control the power in the most efficient way.

The system is extremely flexible. Every type of vessel, with any combination of energy sources, can be controlled by the Energy Mixer. For instance, when a vessel leaves the harbour the operator can choose to sail out without any emissions. When entering the operational field, the operator can change to a mode that optimises the combination of power sources to have both low emissions, as well as the most efficient use of the power sources. On the other hand, instant additional power is required when environmental conditions change.



Propulsion train overview

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Propulsion Train

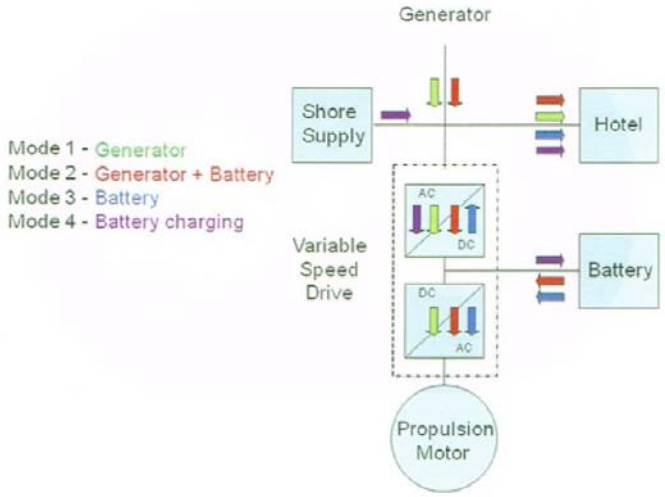
The new ferries are propelled by two Voith Schneider propellers of 375 kW each, which in turn will be powered by a Permanent Magnet (PM) motor of 400 ekW. Three diesel electric generator sets of 368 kVA each are feeding power to a 400 V switchboard, which will supply the frequency converters that turn the PM motor.

The scope also included the delivery of two lithium-ion battery banks per ferry with a total capacity of 700 kWh, each battery bank of 350 kWh is directly connected to its own frequency drive DC bus. Connecting such battery capacity directly to the DC bus is a world first.

However, when the team studied the possibility of connecting the batteries directly to the frequency converter DC bus, a couple of problems were discovered that had to be solved. At the moment, the market is simply not prepared for the use of DC grids, so finding components that are applicable to this solution is extremely difficult. The system's selectivity needed to be solved too. When a short circuit occurs, the response of the batteries is very fast. To get the right selectivity, the design issues had to be overcome. In addition, the forces on the components are so big when a short circuit occurs, that a special solution had to be developed to make the system resistant to these forces.

A battery has a large energy capacity, which can be used almost instantaneously if required. To keep this natural behaviour in control, a proper and safe current control is required; if not, it could be a dangerous source of energy. The solution to control the current of the batteries is simple and is based on the first law of Kirchhoff Li;= 0 But to control the current, the team needed to cooperate with its partners: Vacon, the drive manufacturer, and European Batteries, both Finnish companies.

The automatic current controller had to be installed into the complete system



Four operating modes

Control Loop Without a DC-DC Converter

Other technologies typically use a DC-DC converter in between the batteries and the DC bus of the converters, but Imtech Marine wanted the connection between the batteries and the DC bus to be as efficient as possible. Therefore, the DC-DC was skipped and Vacon was approached with the ambition to create a control loop without a DC-DC converter. A small testbed was built and European Batteries loaned suitable batteries, along with a Battery Monitoring System. The team got the system working manually, but then had to address how the voltage and system could be controlled automatically, hence the need for a current controller. Together with the two Finnish companies, an automatically controlled loop was developed. The team went to Finland where they saw that the prototype of the automatic current controller was working, but only in a test environment. This then needed to be installed into the complete system at Imtech Marino's headquarters in Rotterdam. Several elements all had to work as one system, including the third party deliveries. The Rotterdam based company took care of the interfacing and brought all the elements together in the Energy Mixer which includes: a Power Management System, a Propulsion Control System, an alarm system, and a drive and current controller. To optimise the system, it was a case of very gradually testing it. Because the system produces such a lot of energy, it has the potential to be very dangerous. Therefore, everything had to be carried out extremely carefully. Initially, the team, which comprises some 25 people in the Netherlands and Finland, thought the system could not scale up, but after many, many tiny steps, finally got the system fully operational.

Four Modes

To change the way of using the energy sources, the operator has an interface with a choice of four operating modes.

- Mode 1 - Generators only: This mode is similar to a typical conventional propulsion drive. The propulsion train is supplied by the

- diesel generators. This mode is also called the "fall back" mode. If a fault occurs, the operator can always select this mode to keep the vessel sailing.
- Mode 2 - Generators+ batteries: This is the mode where the Energy Mixer is active. In this mode, the Energy Mixer regulates the energy flow to achieve the most efficient use of power.
- Mode 3 - Batteries only: In this mode the vessel is emissionless. In some cases, such as on a Sunday, when there are reduced services, it may be possible to sail a whole day on batteries alone.
- Mode 4 - Charging: This mode activates automatically when the shore-supply is connected. The system recognises that a shore connection is supplying the main switchboard and starts charging the batteries. This is an automatic process which runs overnight. At the end of the charge cycle, the batteries have to be balanced to keep every single cell inside of all the modules in the same condition.

Bringing a world first to the maritime industry is a challenge and hard work, in this case eighteen months' hard work

Battery Lifetime

The lifetime of the batteries is vitally important and in light of this, European Batteries and Irntach's team developed a control to guarantee battery lifetime. However, the batteries do have to be "treated well". The battery room is conditioned for the optimal working temperature of the batteries and the discharge and charge current are controlled to avoid high currents. Battery temperatures, currents and voltages are monitored and if one of these values reaches a limit, the operator gets a message and is advised to switch to another mode where the batteries are not used.

The batteries have to be treated well

Risk Analysis

When the project started, classification societies did not have the rules and regulations in place for this amount of this type of battery to be installed on a seagoing vessel. Of course, classification has experience with installing batteries on board, but not with this specific type of battery. Therefore, a risk study was conducted, which resulted in a Risk Analysis of batteries on board of seagoing vessels and a Failure Mode and Effect Analysis of the whole system. The outcome of these studies helped the team make the system safe in every situation.

Naturally, the industry is keenly watching developments on the CMAL project and it is also very much a hot topic within the classification societies themselves. Imtech Marine approached the British register with a view to classifying the new concept. This is very much a joint approach as is an industry first. Imtech Marine and Lloyd's Register are assisting each other to get the basic design approved and surveyed and are giving a lot of valuable input for future developments. The successful factory acceptance tests for the first vessel took place in October 2012 and these will take place in February for the second vessel. This has been a relatively smooth process so far.

Harbour acceptance tests and sea trials still have to take place, but commissioning for the first ferry gets underway in March, with trials due at the end of April.

Source: SWZ Maritime - February 2013