Laws and price drive interest in LNG as marine fuel

The use of LNG as a marine fuel is one of the hottest topics in shipping. This growing interest is driven by legislation and price.

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Limiting SOx emissions in Emission Control Areas (ECAs) to 0.1 percent from 2015 and to 0.5 per cent globally from 2020 will effectively ban the use of heavy fuel oil. That means ships will need to shift to low sulfur fuel oil, marine gasoil or LNG. At the same time, the limit on NOx emissions in ECAs (Tier III) from 2016 will force new ships to either install scrubbers or shift to LNG.

Financial factors are also helping the push to LNG. As of today, LNG is the most cost effective marine fuel that complies with the upcoming SOx limits.

Electrical drives

A fixed pitch propeller's direct drive is by far the most efficient way of transmitting the power generated by an ultra-low speed, two-stroke engine to the propeller. However, this configuration is not applicable to all ship types. Ships equipped with medium-speed engines require a clutch and reduction gear, adding some losses to the system (about 2 to 6 percent). Alternatively, these ships can be fitted with electrical drives, allowing engines to act as generators. This increases propulsion losses (about 7 to 11 percent).

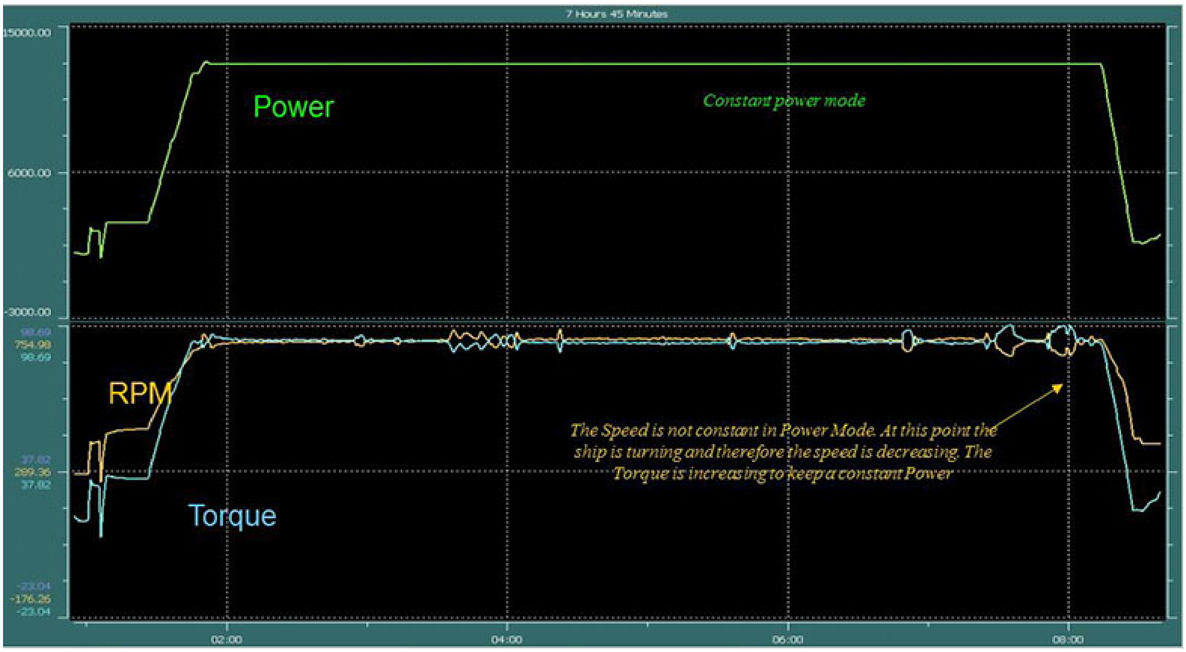
Nevertheless, the electrical drive of fixed pitch propellers offers benefits that in many cases outweigh the lower propulsion efficiency. An integrated electrical power plant enables the designer and operator to better match the running engine capacity with the actual load demand under a wide range of operating conditions through the load-dependent start and stop of generator sets. This allows engines to operate more optimally and more efficiently, which may offset and exceed the higher transmission losses.

In addition to the more commonly known energy efficiency effect, electric propulsion has other benefits when it comes to availability, safety and maneuverability, which will be described in this article. While some of these benefits are evident regardless of the type of fuel used, many become more pronounced with LNG.

Dynamic response

Diesel cycle engines – which include both dual fuel gas engines with pilot diesel ignition and high pressure gas injection engines – are intrinsically slow to respond to power fluctuations, which occur constantly due to variations in the propeller load driven by waves, wind and steering motions.

Electrical drives offer a much faster response to load variations. They can also precisely control the torque, power and propeller speed, minimizing the ship's speed loss due to external factors. In a mechanical system, the engine control system responds to load variations on the propeller by adapting the fuel injection to meet the new power/speed requirements. The new equilibrium point is only achieved when the inlet air reaches the right pressure and temperature, which depends on the pressure increase of the exhaust gases. This iterative process – known as thermodynamic inertia – lies at the heart of the dynamic response of direct drive systems.



1. Load variations are kept to a minimum by keeping propeller load constant during maneuvering of a dual fuel engine LNG carrier.

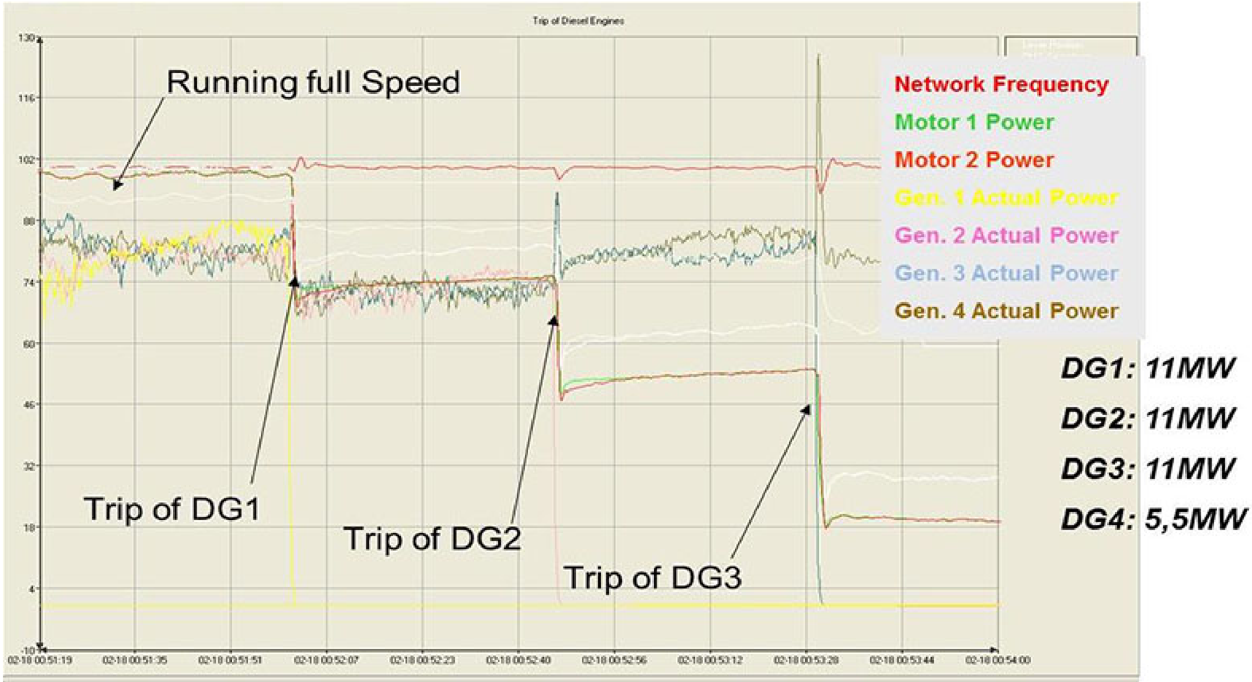
In an electrical propulsion plant, the drive can be optimized to maintain constant power and cope with load variations by adapting the torque and propeller speed. By keeping the power constant, the overall system is less exposed to the dynamic response limitations and can therefore maintain the ship's speed when faced with external factors (such as bad weather). The logged power consumption from a single shaft LNG carrier with electric propulsion and dual fuel engines is shown in Figure 1. This clearly indicates that by controlling speed and torque simultaneously to keep the power constant, propeller load variations are not transferred to power variations in gas engines.

The dynamic response of the propulsion system is also a key element of the ship's maneuvering performance. Handling a ship in confined areas is very risky, requiring high thrust at low speed and on demand. The dynamic response of mechanical systems during maneuvering has benefited tremendously from the introduction of Controlled Pitch (CP) propellers. Nevertheless, electrical drives offer much more control compared with CP propellers. An electrical drive, for example, can provide full torque at zero speed.

Fast load reduction

The engine and electrical power plant are essential to safely operate vessels, in particular ones that use dynamically positioning (DP) and maneuver near shores and harbors. Electric propulsion increases the redundancy of the plant by enabling all engines to provide power to any of the propulsions and thrusters.

Thus the loss of one engine out of, say, four, has a relative small effect on the maneuverability of the vessel. For gas or diesel electric power plants, it is important to keep in mind the risk of cascading failures of paralleled gen-sets. Traditionally, the solution has been to run the power plant in split mode when a higher safety level is required, but this limits the plant's maximum energy efficiency.
New enhanced reliability notations from classification societies allow for the use of closed bus systems also in higher DP class operations. This requires additional efforts in load control and fast protection, which can now be solved through electric propulsion. The effectiveness of load reduction is shown in Figure 2.



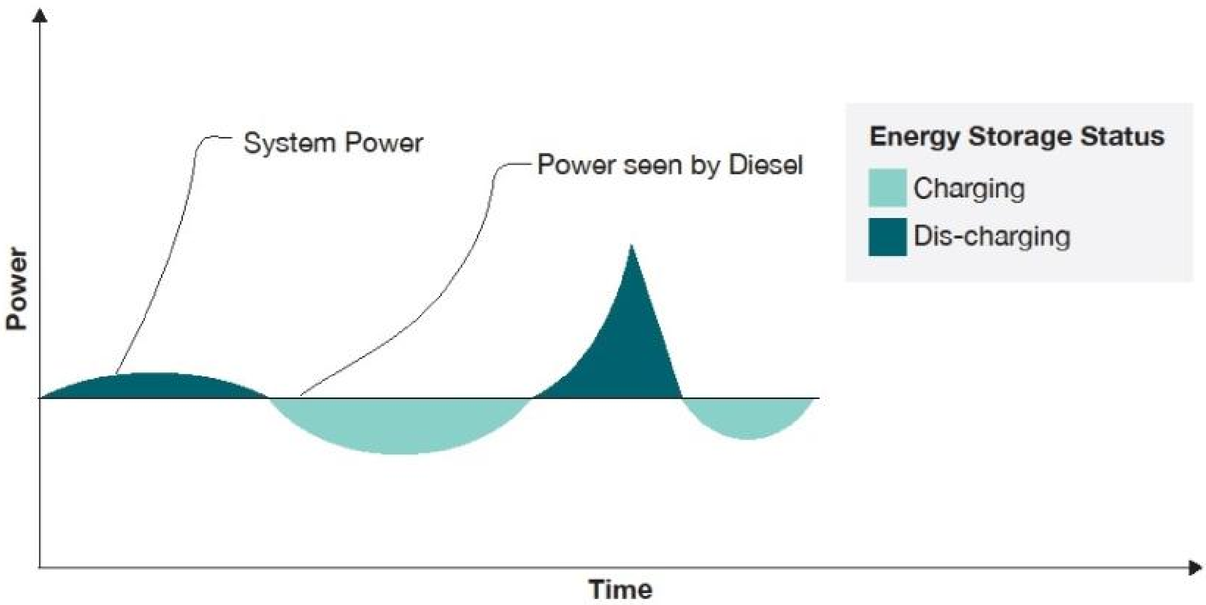
2. Sea-trial recording of load reduction test by tripping, one by one, the dual-fuel engines in an electric propulsion system for LNG carriers.

During a test run, the engines of a four-engine power plant were shut down one by one. The load reduction on the propulsion was controlled fast enough to keep the frequency variations in the network well within the permitted limits, ensuring availability of the remaining power plant – even if the 11 MW engine tripped and only the 5.5 MW engine was left to provide power.

Frequency converters used to drive electric propulsion motors are based on power electronic circuits – high-power components that are switched up to a few kHz to control the torque of the motor. Such converters may control the torque load within milliseconds. This allows for precise control of the load power of the generator sets and permits the engines to operate closer to their maximum load, which also gives the highest energy efficiency and minimum emissions.

Energy storage

Batteries and super capacitors can further enhance the dynamic response of electrical propulsion systems. Energy storage systems can provide energy to sustain peak loads and to fill the time gap between thrust demand and energy production (see Figure 3).



3. Illustration of peak shaving through energy storage.

Electrical drives are capable of providing full torque almost instantaneously, but will normally need to be limited as the engines can usually not provide such load variations. Energy storage systems make it possible to reduce this constraint on propeller performance by providing fast power fluctuations from, for example, the battery, while the gas or diesel engine is exposed to more stable load with slower variations.

This is particularly important for large and frequent load variations (for example, in DP) or in harsh conditions or ice-breaking operations, where the dynamic capability of the station-keeping system directly affects the vessel's performance. This also raises the average loading of the engines and allows them to operate more energy efficiently as they do not need to meet dynamic peak loads.

Partial load

The specific consumption of an LNG engine at 50 percent load is about 6 to 8 percent higher than at full load. Ships that operate regularly on partial load can improve their overall fuel consumption by using an electrical propulsion plant. The generators used match the produced load demand, optimizing overall fuel consumption. Particularly for DP vessels – where redundancy requirements result in very low average engine utilization – the specific fuel oil consumption is much higher than at optimal load, which is typically 85 percent. This can be further enhanced by using DC distribution (ABB's Onboard DC Grid), which allows generators to operate at variable speed and closer to their most efficient power/speed ratio.

Emissions

One of the biggest benefits of LNG engines over conventional fuels is lower emissions. Combusting LNG does not produce SOx, substantially reducing NOx and CO2 emissions. However, these benefits can easily be wiped out by methane slip, which occurs when the gas injected into the combustion chamber is not fully burnt and escapes through the exhaust, particularly when operating in partial load.

Methane slip can be minimized by using electrical propulsion; the power management system selects the number of online generators to optimize cylinder pressure so that the gas injected into the combustion chamber is fully burnt. Onboard DC grid, where the engine speed can be varied and the cylinder pressure can be kept at a higher level, also allows for more complete combustion with less methane slip.

Methane number

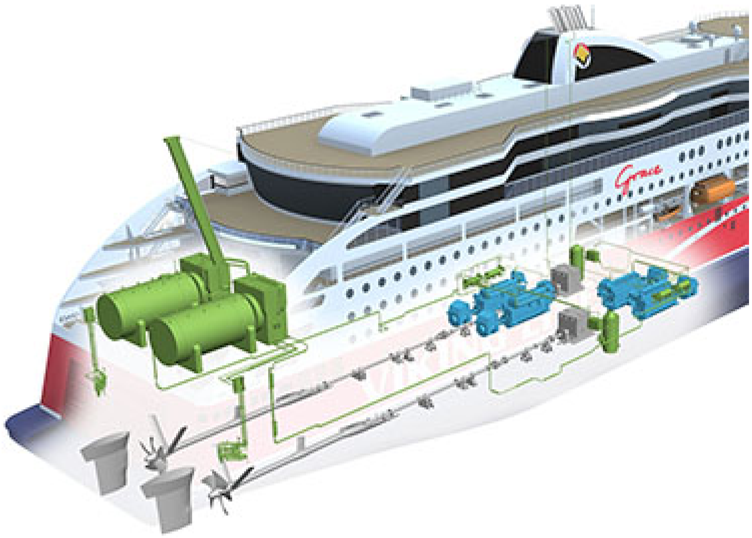
Both dual fuel (DF) and lean burn spark ignited (LBSI) engines are very sensitive to the quality of gas. The methane number is equivalent to the octane number in gas and indicates its knock resistance. A high methane number is good for the performance of the engine, while too low a number can lead to knocking and cause extensive engine damage. The methane number depends on the origin of the gas and can vary quite substantially (from 70 to 90 in an index of 100).

If the gas has a low methane number, the engine needs to be derated to prevent knocking and damage, which affects propulsion. However, an electrical propulsion plant lessens this effect because it is possible to install additional power without compromising propulsion efficiency at the design point (service speed).

LNG electrical propulsion: Viking Grace

Viking Line recently took delivery of Viking Grace – the first large ferry powered by LNG – from STX Turku Shipyard. The company decided on LNG propulsion mainly to comply with ECA SOx requirements and because of the low price of LNG compared with heavy fuel oil.

Viking Grace, operating the Turku-Stockholm route in the Baltic Sea, is about 218 meters long and 31.8 meters wide with a gross tonnage of 57,700. She can carry 2,800 passengers and has a service speed of 21.8 knots.



The vessel is equipped with four Wärtsilä 8L50DF engines – dual fuel engines that use about 1 percent of diesel oil as a pilot fuel to ignite the gas-air mixture. Each engine is connected to an ABB generator of 8191 kVA at 500 rpm, producing total power of 30,400 kW.

Each of the two fixed pitch propellers is driven by a 10.5 MW ABB ACS8 synchronous motor that is controlled by an ABB AC6000 frequency converter and fed by two propulsion transformers that convert electricity from 6600 V to 3300 V.

ABB also supplied two 2300 kW motors for the stern transversal thruster and one 1500 kW motor for the bow transversal thruster. Two 600 kW AC motors were also supplied by ABB as well as the four 2500 kVA converters.

The propulsion drives supplied by ABB were programmed to take into account the dynamic response of the engines to ensure that the power plant remains stable during different operational modes.

Source: Generations magazine published by ABB Marine & Cranes