Electric propulsion for LNG Carriers

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Full-size LNG carriers with dual fuel diesel engines and electric propulsion are now under construction in France. The authors present the benefits and design features of electric propulsion systems in LNG shipping applications.

The current world usage of LNG is about 110 million tons per year and this is growing at a rapid rate. The availability of LNG in the near future is expected to increase significantly, which will lead to an increase in the number of LNG carriers. The use of electric propulsion has become an attractive solution, due to its high overall efficiency, increased cargo capacity, and possible increased size of future LNG carriers.

Power and propulsion for LNG carriers

For all vessels with electric propulsion the power plant is essential. The power plant consists of several medium speed gas/diesel engines, which drive the electric generators. The generators are connected in a common grid, to the main electrical switchboard. All loads, including propulsion, thrusters, auxiliaries, and ship systems are normally fed from this grid, and the total load is shared between the running generators. The configuration of the power plant is based upon total installed power, operating modes, flexibility and redundancy requirements, and equipment cost. The number and rating of power generating sets must be optimized to achieve the desired flexibility in view of fuel economy for prime movers, operational profile and service factor. The purpose is to achieve optimal loading of the running generator sets during the different operation modes.

The voltage level of the main power plant is selected so that load current and short circuit levels are kept within the technical limits of the equipment, and also to optimize the total cost of the installation. For installed power levels above 8-10 MW, medium voltage switchboards are the best technical and cost optimal solutions providing arc-proof solutions with high safety with regard to damages and injuries. With increasing total power, the power generating voltage will increase also, e.g., to 6.6 kV or 11 kV.

For full size LNG carriers and future larger size LNG carriers the optimum voltage levels are 6.6 kV and 11 kV, respectively.

Figure 2 - Efficiency from fuel supply to propeller shaft of a Dual Fuel Electric Propulsion plant compared to a Steam Propulsion plant

Propulsion efficiency: At rated load the reported efficiency of the DF engines are typically about 47%. Including the transmission losses, which are in the range of 8-10%, the overall efficiency is approximately 43% calculating from fuel consumption to propeller shaft power. The reported efficiency for the steam propulsion unit (including boilers, steam turbine and gear) is typically less than 30%. For part load operations as in manoeuvring mode or operation in areas with speed restrictions the efficiency difference between steam and electric propulsion is even higher. This is due to the power plant principle where the power generation part consists of several engines operating in parallel and an optimum number of prime movers is always selected to match the load demand from the propellers and ship service load. Figure 1 gives an illustration of the efficiency.

Total installed power: On the conventional LNG carriers today there are 3 – 4 auxiliary generators for the cargo handling plant. The total power is about 10 – 12 MW with medium voltage switchboard installations. The majority of this power is only utilized while the ship is at the terminal for cargo unloading.

For vessels with electric propulsion one common power plant is utilized for both propulsion and cargo unloading. This means that the total amount of installed power can be reduced with electric propulsion systems because the cargo unloading plant and the propulsion plant are not used simultaneously. For example an LNG carrier with a requirement of 26 MW of propulsion power and 10 MW for cargo unloading would require about 39 MW of installed power capacity (including 10% turbine margin) for the conventional propulsion drive system, compared to about 35 MW for the electric propulsion system. This would mean additional installed power capacity, and also additional continuous power consumption of about 5 MW at seagoing conditions. The total installed power would then increase compared to steam propulsion and even more compared to electric propulsion.

As the reliability requirements for LNG carriers are extremely high, there is reluctance in the market to use two stroke engines for propulsion of LNG carriers. However, the relatively low efficiency of the propeller system, compared to that of the steam turbines, has long been considered as an alternative propulsion system for future LNG carriers. This propulsion concept is commonly used in other commercial tanker fleets, so this also has been considered as an alternative propulsion system for LNG carriers. The main obstacles so far have been the handling of BOG and the propelling elements and the associated reliability compared to today’s steam propulsion.

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peller with medium speed motors and gearboxes and twin propellers with direct slow speed motors. Other configurations such as using medium speed motors with gear also for the twin propeller case and two tandem slow speed motors on the single propeller case are also being considered. As shown in the configuration drawings the 50% redundancy is kept all the way down to the propulsion motors, and besides the different configurations of the propulsion motors the electric power generation, distribution and propulsion converter configurations are the same for both propulsion alternatives.

Being the major consumer, the propulsion drive is also the main source of harmonic currents. By correct dimensioning of power plant generators and propulsion drives it is possible to get the harmonic distortion level within the classification limits without the use of additional filtering. The most efficient and reliable measure is to increase the pulse number of the drive system. For the LNG carriers with propulsion power of more than 20 MW this can be applied with minor cost impact. Using the ACS 6000 converters from ABB, standard diode bridge rectifiers are used giving a constant high power factor to the network and by combination of the rectifier bridges in 12- and 24-pulse solution the harmonic distortion level is minimized. With 24-pulse solution the THD (Total Harmonic Distortion) level of the main voltage is normally below 5%.

Fuel consumption and emissions

One of the main drivers to shift from steam to electric propulsion system is the improved efficiency as illustrated in Figure 1. Operational costs of LNG vessels consist of several parameters such as fuel costs, maintenance costs, crew costs (including training), ship capital cost, etc. As the fuel costs or fuel consumption are a major part of this, the improvement of efficiency by going electric will lead to significant savings on fuel consumption and hence the operational costs.

To visualize these savings an example calculation is given below for a typical operation profile of 7500 hours per year with full speed (19.5 knots). Half of this is assumed as laden voyage and half is assumed ballast voyage. The time for manoeuvring and harbor operations are not included in the calculations. Calculations are performed for three propulsion alternatives: Steam-turbine, two-stroke mechanical with reliquefaction and dual-fuel electric propulsion. For the steam turbine propulsion vessel supplementary Heavy Fuel Oil (HFO) is assumed used in the boilers in addition to the BOG, and 5 MW power consumption for the reliquefaction plant. For the electric propulsion vessel forced boil off is assumed to supplement the natural BOG. A typical vessel of 140,000 m³ is assumed with a propulsion power of 26 MW in laden condition and 25 MW in ballast condition.

The results are given in Figure 3 and show a clear advantage of the dual-fuel electric propulsion system regarding fuel consumption and emissions. For the fuel consumption both the two-stroke and electric propulsion alternative are superior to the steam solution. This is basically due to the increased efficiency of the propulsion plant. Even including the electrical transmission losses the electric solution has also lower fuel consumption than the two-stroke solution because the reliquefaction plant additionally requires about 5 MW continues power during normal operation of the carrier.

Over the last years a growing focus on environmental conditions has lead to a stronger focus on utilizing cleaner fuel systems. Using LNG as fuel gives clear benefits for the emissions of NOx and SOx as indicated in Figure 4. Utilizing forced boil off gas also for the steam propulsion system would lead to lower emissions of SOx and NOx. The CO2 emissions are strongly related to the fuel consumption and together with the lower carbon content in LNG compared to HFO and Marine Diesel Oil (MDO) this gives a clear advantage for the electric propulsion system with respect to CO2 emissions.

Reliability and Availability

For LNG Carriers the main task is to deliver the LNG cargo at the terminal at the scheduled time. Due to limited storage capacity at the terminal the whole LNG supply system is based on regular arrival of the LNG carriers. The vessels are also normally chartered for 20-30+ years to ensure a stable and reliable supply of LNG. In that respect the propulsion system is not allowed to fail in such a way that the vessel will be late arriving at the terminal. When introducing the electrical propulsion system as an alternative to the conventional steam propulsion system it must be proven to have the same or higher level of availability.

ABB has long experience with reliable electric propulsion systems for many types of vessels, and has delivered to more than 350 vessels ranging from cruise vessels, ferries, ice breakers, shuttle tankers, drilling vessels/risks, field support vessels, etc. The propulsion power has been varying up to more than 20 MW for a single propulsion motor. Using the experience from these projects the electric propulsion system on LNG carriers is designed to meet the highest standards of safety and reliability.

World’s First Full Size LNG Carriers with Electric Propulsion

For Gaz de France’s first two 154,000 m³ LNG carriers with electric propulsion, ABB is delivering the propulsion drive system which consists of propulsion motors, frequency converters, propulsion transformers and the MV (Medium Voltage) switchboards. The vessels are being built at Chantiers de l’Atlantique, one of the pioneering yards with respect to innovative propulsion systems and technical solutions. Together with Gaz de France, the first shipowner to order LNG carriers with electric propulsion, a breakthrough for Dual Fuel electric propulsion system has been achieved. More information can also be found in [1].

The 2 x 14 MW medium speed propulsion motors are connected to a common gear-box for driving a single fixed pitch propeller. Each motor is controlled by an ACS 6000SD frequency converter, which is the latest generation of MV (medium voltage) drives from ABB utilizing IGBTs (Integrated Gate Commutated Thyristors) as switching devices and the ABB patented DTC (Direct Torque Control) principle for synchronous motor drive. The DTC control is developed for optimizing the dynamic torque response and minimizing the torque ripple on the motor shafts, hence leading to minimized machinery-induced vibration and noise levels.

Small LNG ship with electric propulsion

One small LNG carrier with electric propulsion is already in operation. The 1100 m³ LNG carrier “Pioneer Knutsen” was delivered from the Dutch yard Bilbama in March this year, and has been in operation along the Norwegian west-coast since then. The main propulsion consists of 2 x 900 kW azimuth thrusters driven by low voltage frequency controlled motors delivered by ABB. Power production is generated by 2 x 900 kW Mitsubishi gas engines and 2 x 640 kW Mitsubishi diesel engines. The gas engines are fueled by BOG while the diesel-engines are supporting with additional power if required.

References


Jan Fredrik Hansen graduated from the Norwegian Institute of Technology with a M.Sc. in Electrical Power Engineering in 1995. He also holds a PhD degree in Engineering Cybernatics on the topic of Modelling and Control of Marine Power Systems (year 2000). He joined ABB Marine in Oslo in 1999 working with electric propulsion systems. He is now Technical Advisor with the main focus on LNG carriers.

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