Optimising efficiency in DFDE for LNG carriers

The best of both worlds

Optimisation is the key to unlocking continued benefits for dual fuel diesel electric (DFDE) propulsion solutions in the LNG carrier segment.

DFDE propulsion has been widely used by LNG carriers (LNGc) over the course of the last decade. However, the recent introduction of two-stroke dual fuel mechanical propulsion has shaken up the segment. This study compares the propulsion efficiencies of these two rivals, discussing the pros and cons of each. The results clearly demonstrate that DFDE still has much to offer the market.

Background

This study utilises DNV GL's COSS-MOS computer process-modelling platform – a comprehensive tool featuring 200+ component models and 2500+ non linear equations. Here the platform has been used to assess various machinery configurations with respect to energy efficiency and economic performance for a case specific vessel, taking into account vessel speed and various trading profiles. All data relating to the LNGc examples studied is either supplied by ABB, based on equipment delivered for on-going projects, or publicly available data from manufacturers.

The study follows an actively trading vessel equipped with a variety of sensors continuously measuring more than 2000 parameters to verify the models used and prove their accuracy.

The main results show that DFDE delivers highly competitive fuel consumption if optimised, and is superior to the mechanical solution in the speed range below 16 knots and equal to it above 16 knots.

Delivering benefits

1) Fuel efficiency

According to the findings in this study, an optimised DFDE propulsion system for a LNGc will have better overall efficiency and less fuel consumption than a two-stroke mechanical solution. A DFDE solution with a four-stroke engine uses less pilot fuel and more LNG. By optimising the PMS strategy – shutting off engines - even lower fuel consumption can be achieved.

DFDE propulsion also negates the need for an auxiliary power plant as less installed total power is required on-board. Standard two-stroke solutions require auxiliary power plants, typically of 10MW, for vessel loading/unloading.

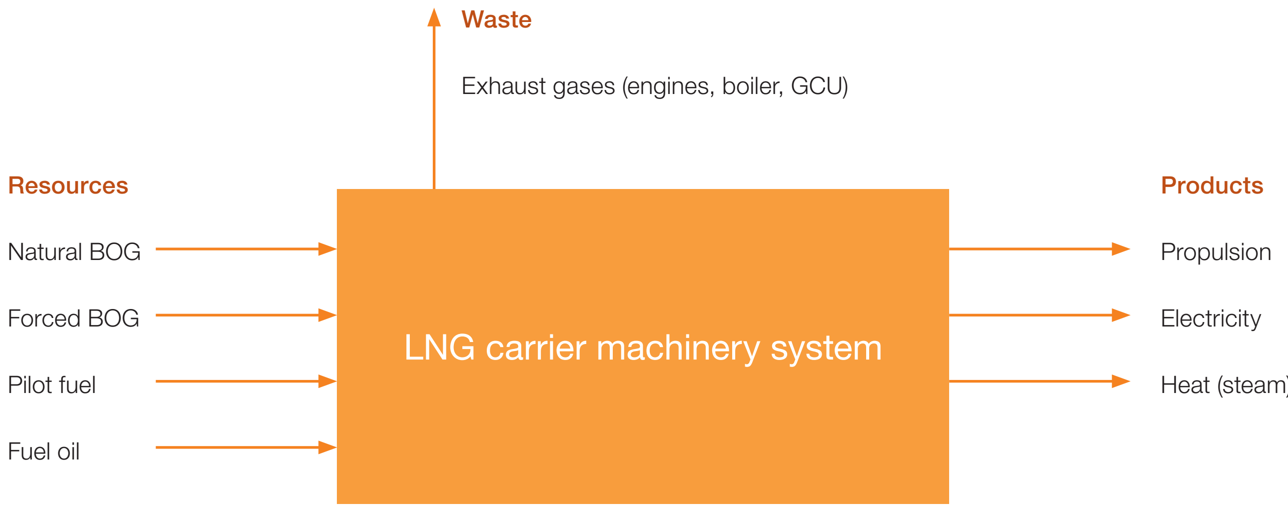


Figure 1: LNG carrier machinery system

2) Proven technology
DFDE propulsion units have been by far the most commonly used propulsion systems for LNGcs over the last decade, with ABB establishing itself as market leader. The firm delivers both induction motors and the more efficient synchronous propulsion motors, utilising its effective on-site commissioning organisation to fulfil orders for the biggest international yards. As of September 2015, over 100 LNGc vessels have been fitted with DFDE propulsion from ABB.

3) Flexibility
DFDE propulsion allows ship owners to adapt to the technology of tomorrow, with possibilities for installing alternative energy storage mediums and/or energy transformation devices, such as fuel cells. Hybrid power plants with energy storage capabilities reduce operational costs by optimising the dual fuel engine loads. In addition, they improve safety, availability and increase dynamic performance.

ABB's Dynamic AC concept, often referred to as DAC, enables optimisation of total fuel consumption in the vessel by adjusting the rotational speed of the dual fuel generating set and allowing the frequency to vary within a specified range. A fixed 60Hz frequency is not required to operate the propulsion system. The small proportion of consumers who require fixed frequency would need to install an island converter. LNGc simulations on specific trade routes have indicated that fuel savings of up to 6% can be achieved.

Optimising efficiency

This study marks the first time a system provider has cooperated with DNV GL for an LNGc machinery assessment. To date, the market has generally held the perception that two-stroke dual fuel solutions are superior to DFDE propulsion in terms of efficiency. However, with optimisation measures and updated figures for DFDE propulsion systems it was found that, compared to previous studies, overall efficiency was greatly enhanced.

The LNG carrier integrated marine energy system

On board an LNGc there is a multi fuel and multi product energy system. All inputs and outputs are taken into account when considering overall vessel efficiency.

If the boil off gas (BOG) rate of the LNG containment system produces more gas than consumed, the excess boil off must be either burnt in the gas combustion unit (GCU) or re-liquefied back into the tanks. If the BOG rate produces less gas than needed, the boil off must be forced.

Optimising PMS strategy to enhance efficiency

By optimising a vessel's PMS strategy – for example, by increasing the loading of some engines while shutting others off – higher overall efficiency can be achieved. For Wärtsilä four-stroke engines running on gas, which normally drive ABB generators, relative fuel consumption decreases with loading, and reaches its minimum at 100% of maximum continuous rating (MCR). Higher loading gives a better combus-

Ship overall efficiency – comparisons

Fuel oil, pilot & cargo energy consumed – Propeller, Electricity & Heat demand

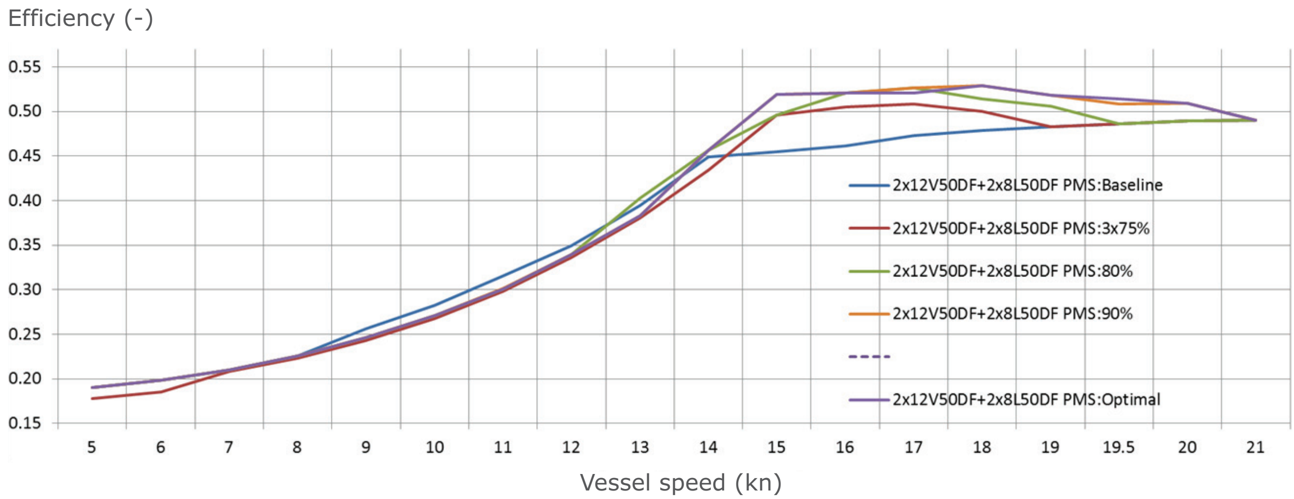


Figure 2: PMS strategy efficiency improvements over speed range

tion process, while less running hours for each engine reduces service cost. A fast load reduction feature is already built into the frequency converter, reducing the risk of both overloading the generators and black outs.

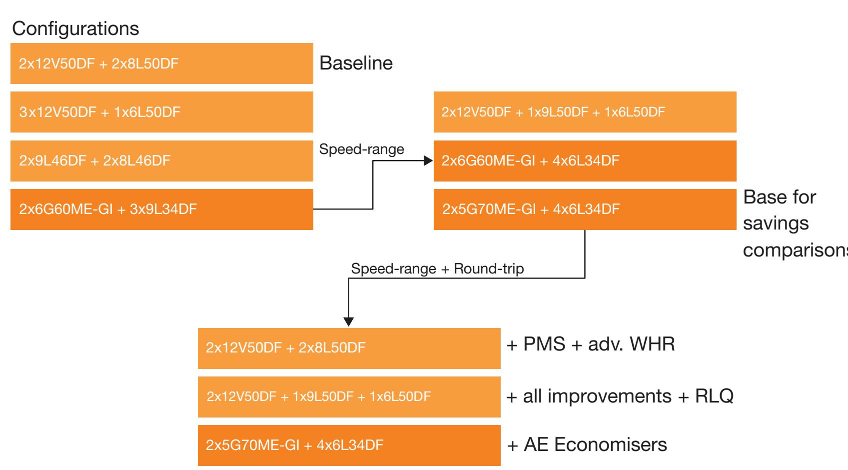
PMS strategies

- Baseline – A 'business as usual' scenario as derived from historical data. Equal load sharing.
- 3x75% – three engines on continuous operation, switching to four when 75% load is exceeded, switching to two when the load drops below ~30%.
- 80%/90% - Starting with one engine at low loads, a new engine comes online when loading of the engines exceeds 80 or 90% of MCR and vice versa.
- Optimal – Same as 80%/90% but with a variable maximum load limit, giving approximately 1000kW reserve capacity for any engine combination.

Compared to the PMS baseline, a significant increase in efficiency is achievable, especially at speeds above 13 knots. An optimal PMS strategy was found to have the biggest single contribution to increasing overall efficiency for the DFDE concept. It should therefore be implemented in future LNGc newbuildings.

Engine layout

A 174kbm LNGc will traditionally have four four-stroke engines of various sizes. Increasing the number of different engine sizes also increases



Simulated configurations: This configuration has improved performance in the high-speed range

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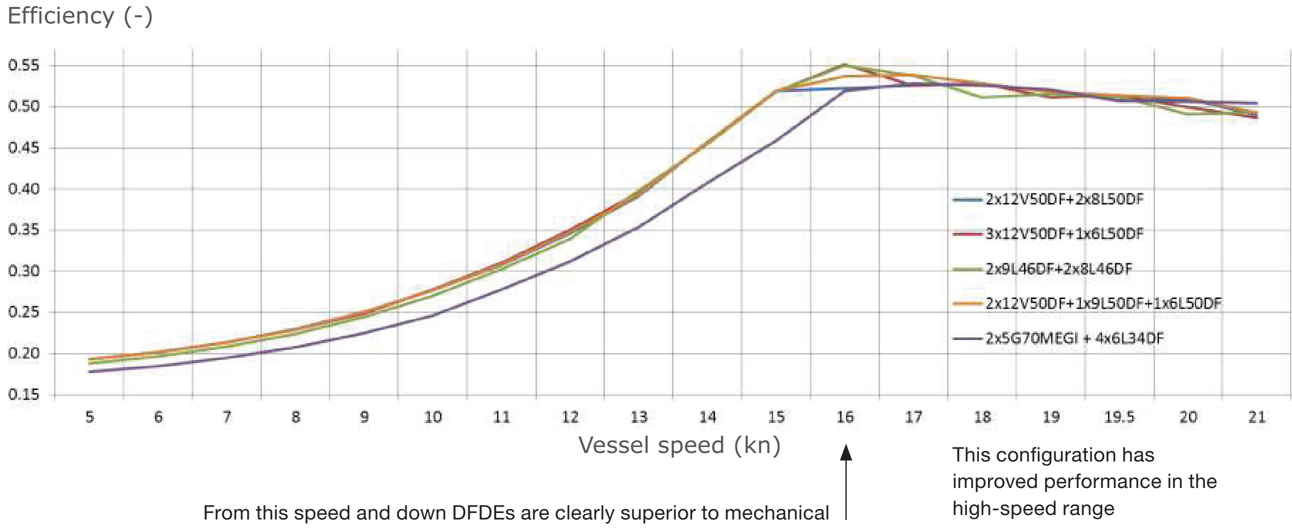

Figure 3: Speed range results for various configurations of machinery lay out

possible power combinations, thus augmenting the power resolution. Comparing DFDE to two-stroke dual fuel mechanical propulsion over the vessel speed range, it is clear that DFDE is still very competitive and should be a feasible solution for owners.

Waste heat recovery

Steam is used for various applications on board an LNGc. Its contribution to overall power consumption for the vessel is significant (up to 3MW). The four-stroke Wärtsilä engines have higher exhaust temperatures than the two-stroke engines, giving the four-stroke higher potential for exhaust economizers / waste heat recovery (WHR) to create steam.

Usually economizers are dimensioned to create steam and fulfil the vessel's steam demand at design speed. However, if the economizers are increased in size, more steam can be created over the speed profile and therefore overall efficiency can be enhanced.

When adding extra waste heat recovery, more optimal PMS and an optimised engine layout, fuel savings of up to 14% are achievable when compared to the DFDE baseline, and of up to 12% compared to two-stroke dual fuel solutions, at certain speeds.

Partial re-liquefaction

Re-liquefaction plants are not standard on LNGcs due to high CAPEX. In this study a smaller/partial plant with a capacity of 500kg/h was simulated as an option. Dependent on LNG price and the speed profile of the vessel, partial re-liquefaction may be feasible.

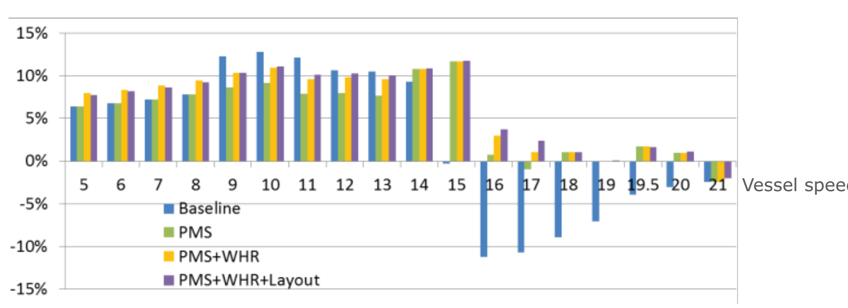

Figure 4: Fuel savings relative to two-stroke engine

Effect of operating profile on technical and economic performance

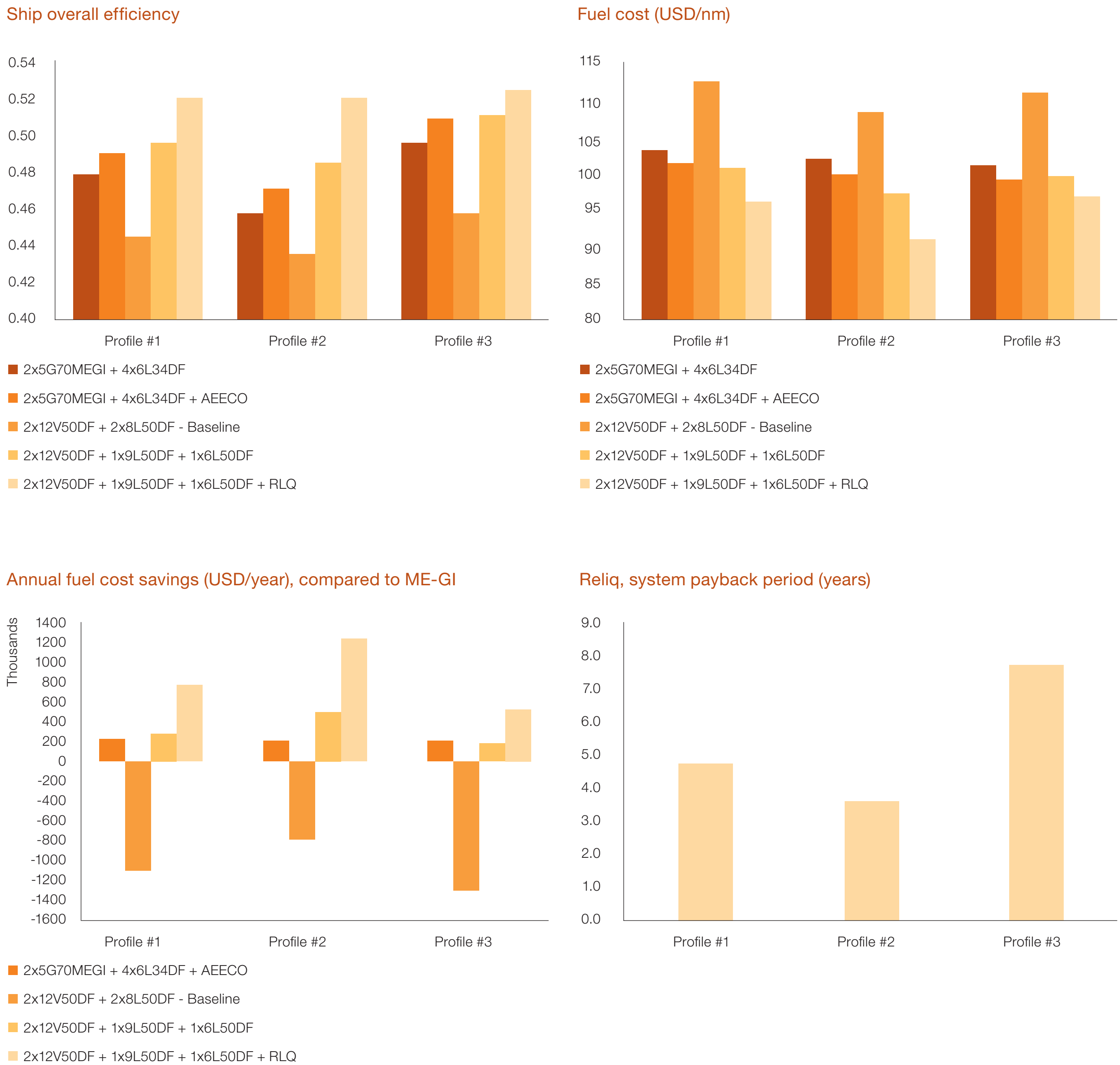

Figure 5: Round trip results

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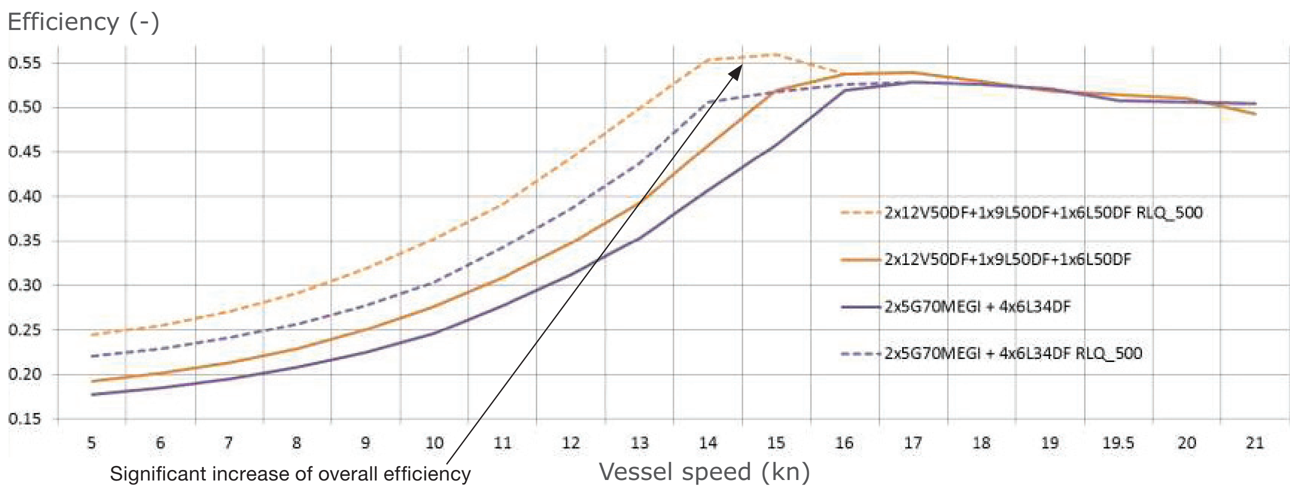
Fuel oil, pilot & cargo energy consumed – Propeller, Electricity & Heat demand



Partial re-liquefaction

Round trip results

When considering a vessel round trip, data for the following sailing and non-sailing modes must be considered.

- Laden
- Ballast
- Loading
- Unloading
- Anchorage loaded
- Anchorage ballast

The characteristics of the round trip profile are as follows

- Speed distribution
- Hours in each mode
- Steam demand
- Propulsion power
- Electricity demand
- Boil off gas rate

The route used in this study was a typical LNGc route, from west coast USA to Singapore. This route has a distance of 7200nm. Three different round trip profiles were simulated, with the result that the optimised DFDE propulsion system was shown to be the most fuel (and therefore cost) efficient solution.

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