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Diesel Electric Propulsion for Offshore Vessels

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SYNOPSIS

This paper is aimed at exploring the different propulsion system solutions for offshore vessels, with focus on the advantages of a diesel-electric solution including: installation, fuel consumption, emissions and maintenance costs. Furthermore, the paper includes a study on the experiences of leading industry offshore vessel operators with diesel-electric propulsion systems.

INTRODUCTION

Electrical propulsion drives aboard vessels is not a concept that has emerged in the past 20 years; in fact, the first electric propulsion units were installed on transatlantic passenger vessels in the 1920s. The prime movers for these vessels were turbo-electric steam plants. However, the evolution of the 2-stroke diesel engine in the 1950s on merchant ships precluded the viability of electric propulsion drives. In the 1970s, new technology such as variable speed electric drives and an increase in power density on medium speed engines gave rise to a new generation of electric propulsion plants.

Today, the demand for electric propulsion continues to grow across a wide variety of marine segments and vessel types. Over the past 10 years, the offshore segment has seen a steadily increasing number of electric drives installed in new vessels, and the trend will continue, most probably at an increasing rate; all the electric drives are likely to have diesel engine prime movers.

Over the past 30 years, the key drivers for electric propulsion have grown in number. Initiated by the cruise market, the desire to provide a higher quality experience for cruise ship passengers was the impetus for the second generation of electric drives. With the advent of variable speed electric drives, a diesel-electric solution was not only viable, but more cost effective. It gave cruise ship owners the ability to provide a better service through an increase in comfort thanks to the reduced vibration offered by electric drives. Furthermore, inherent in most electric drive propulsion configurations is an increase in prime mover redundancy that translated to a more reliable vessel schedule for passengers.

Moreover, due to the favourable dynamic performance characteristics of electric propulsion drives, icebreakers were also one of the first vessel types to find success in diesel electric drives. While on mission, the icebreaker experiences frequent and drastic changes in load, and this favours the less load sensitive electric drive propulsion arrangement.

The emergence of diesel electric propulsion aboard offshore vessels did not come into focus until mid-1990. While there were several factors that contributed to the viability of electric propulsion in the offshore market, the single biggest factor was the market-driven need for dynamic positioning (DP) for platform supply vessels (PSV) and AHTS vessels. This, coupled with the availability of variable speed thrusters, spawned the first electric propulsion plants in this market.

As previously mentioned, there were several factors that led to the emergence and the continuing increase of electric propulsion in the offshore vessel market. This paper is aimed at illustrating all of the advantages of diesel electric propulsion for offshore vessels, and Caterpillar's well-positioned product portfolio for this market.

INSTALLATION FLEXIBILITY

Traditional direct drive diesel electric installations require several unfavourable compromises for an offshore vessel owner. The open flat deck aft of the forward house on typical PSVs presents a challenge for exhaust gas piping, as aft stacks are not viable in most cases. Therefore, long line shafts are required between the forward located diesel engines and the vessel's propellers. This also reduces cargo or fuel storage aft below the main deck. An electric propulsion system eliminates the long line shafts and their alignment between the propeller and the engine. The shaft is substituted with a power distribution cable that supplies electrical power from the main switchboard to the propulsion motors. This both eliminates the cost associated with the shafting and allows for additional tank space below the main deck aft.

MANOEUVRABILITY

The manoeuvrability of electric drive systems is unbeatable. In fixed pitch propeller applications, limited torque is available at low engine rev/min, whereas with electric propulsion vessels, maximum engine torque is available at all propeller speeds. This is best demonstrated in reversing situations. While a controllable pitch propeller can minimise this issue with direct-coupled diesels, the manoeuvrability of electric drives is unsurpassable when coupled with azimuthing and tunnel thrusters.

NOISE AND VIBRATION

The diesel electric installation eliminates the mechanical linkages between engine, gearbox and propulsor, reducing mechanical vibration and structure-borne noise. Moreover, with an electric drive installation, the diesel generator can be completely isolated into independent engine rooms to improve acoustic signatures. As mentioned on the previous page, this was one of the key attributes that attracted cruise ship owners to diesel electric propulsion systems.

RELIABILITY

Reliability is paramount in the offshore supply business. Day rates for today's high-tech PSVs and AHTS vessels demand high reliability by their charterers. Most charter contracts set out severe financial penalties to the vessel operator for down time. The diesel electric propulsion system achieves higher reliability through redundancy and power distribution flexibility. A typical diesel electric offshore vessel will have three to six diesel generators that provide electrical power for propulsion, hotel load, vessel control, and auxiliary power. A single generator failure will typically not negatively impact the vessel's mission.

EMISSIONS AND FUEL CONSUMPTION

Emissions and fuel consumption are both critical considerations in all commercial applications. International and local regulatory bodies continue to implement more stringent emission limits for marine engines regarding NOx and SOx reductions. These measures are clearly for the good of society and in the long run will benefit us all. However, with emission reduction in diesel engines, especially NOx reduction, the impact on fuel efficiency is not always positive. In fact, maintaining or improving fuel efficiency while reducing NOx emissions is one of the greatest challenges for engine manufactures. In basic terms, to lower NOx reductions through internal combustion technology, the engine manufacturer must lower the temperature of combustion. By lowering the peak firing temperature, lower NOx emissions may be achieved.

Given the limited advances in fuel efficiency of diesel engines vis-à-vis emission reduction strategies and rapidly increasing fuel prices, diesel electric propulsion installations offer offshore operators an opportunity to reduce fuel consumption, in some cases as high as 30 per cent, depending on the vessel's operational characteristics.

The opportunity to reduce fuel consumption with diesel electric propulsion systems comes from the system's unique ability to shape the load profile of the system's diesel engines. All diesel engines operate most efficiently at near rated rev/min and between 75 per cent and 100 per cent load (power). *Figure 1* below shows the typical fuel efficiency vs power relationship that clearly depicts the 'sweet spot' in terms of fuel efficiency for diesel engines.

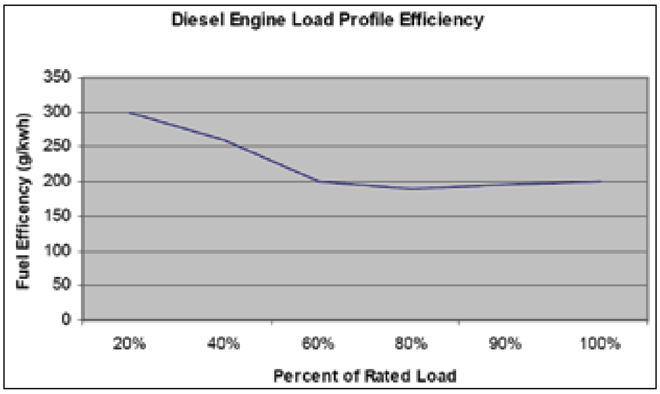

Figure 1: Typical fuel efficiency vs power relationship.

The ability of a diesel electric solution to shape the load characteristics of diesel engines is supported by multiple smaller engines as opposed to two main engines mechanically coupled to the propellers. In diesel electric installations, fuel consumption savings increase with the percentage of vessel operations performing dynamic positioning, station keeping and manoeuvring, all of which typically require low load demands. In traditional diesel mechanical solutions, large high speed or medium speed engines operate for long durations at low load inefficiently. However, at rated load, the mechanical driven solution is more efficient due to energy conversion losses associated with diesel electric propulsion installation.

The crossover point whereby a diesel electric system becomes more efficient in terms of operation profile is when the vessel spends more than 35 per cent of its time in dynamic positioning or manoeuvring modes. In transit mode, where the engines are operating at between 75 per cent and 100 per cent load, the mechanical driven arrangement is more efficient due to the electrical losses in the diesel electric solution. *Figure 2* illustrates the typical losses of the two drive systems.

Efficency Losses	Diesel Electric Drive	Mechanical Drive
Generator	5.0%	0.0%
Transformers	0.5%	0.0%
Frequency Converters	2.0%	0.0%
Motors	4.0%	0.0%
Gearboxes	0.0%	3.0%
Line Shaft Bearings	0.0%	1.0%
Total Losses	11.5%	4.0%
Total Drive Line Efficency	88.5%	96.0%

Figure 2: Typical losses of the two drive systems.

Another important consideration to the overall efficiency of the drive system is hydrodynamic efficiency of the propellers. At low load operation and design transit speed, a variable speed fixed pitch propeller offers better efficiency that a controllable pitch propeller (CPP). However, the CPP is more efficient over a wider range of speed. Moreover, podded drives for diesel electric plants offer vessel owners additional increases in hydrodynamic efficiency.

MAINTENANCE

When considering total owning and operating expenses, the cost of maintenance must be considered. A clear advantage of the diesel electric solution is the ability to install common engines with common parts and tooling. Additionally, with commonality of engine models there is also the benefit and convenience of common maintenance routines and crewmember training.

TOTAL OWNING AND OPERATING COSTS

Ultimately, a vessel owner's choice on the propulsion system for a vessel boils down to total cost of the solution over the lifetime of operation. The major cost areas include:

1. Capital costs for equipment;
2. Installation cost;
3. Fuel consumption;
4. Maintenance;
5. Downtime costs;
6. Operational opportunity costs (lost cargo space for mechanical drive system).

As a rule of thumb, if the auxiliary power required for the vessel, including hotel load, is near or exceeds the power required for propulsion, the diesel electric solution achieves a lower total owning and operating cost over the mechanically driven vessel.

As previously mentioned, the load profile for a vessel will also be a large determining factor for which system is more cost effective in the long run. Moreover, as fuel prices continue to rise, so will the operating cost differences between solutions based on a given vessel duty cycle.

CATERPILLAR ENGINES FOR DIESEL ELECTRIC APPLICATIONS

Caterpillar Marine Power System (CMPS) is the leading manufacturer in providing diesel generators for electric propulsion systems in offshore vessels. Today, the most popular engine family for these applications is the 3500 series engines. Caterpillar offers a complete range of EPA Tier II and IMO compliant engines for diesel electric propulsion solutions that are specifically certified for diesel-electric propulsion operation. Caterpillar will continue to develop premium products for diesel electric propulsion solutions that will enable vessel owners to operate their vessels efficiently and reliably.