Parallel hybrid propulsion for AHTS

A compromise between performance, energy efficiency, and investment

TOR ARNE MYKLEBUST, ALF KÅRE ÅDNANES - Electric propulsion in platform or offshore supply vessels (OSV) has been used since the early 1990s. Advances in technology mean that today there are several optimal propulsion systems that reduce fuel consumption and environmental impact, simplify design and construction, better utilize onboard space and create an improved working environment for the crew.

One of the reasons for the suitability of electric propulsion for OSVs is the large variations in the load profile of propulsors and thrusters. Total engine capacity has to be dimensioned to achieve the design speed of the vessel, or the dynamic positioning (DP) capability in the worst weather situations. As most newbuild vessels are classified as DP 2, with redundancy requirements, the total installed power might be much higher than that required for average loads.

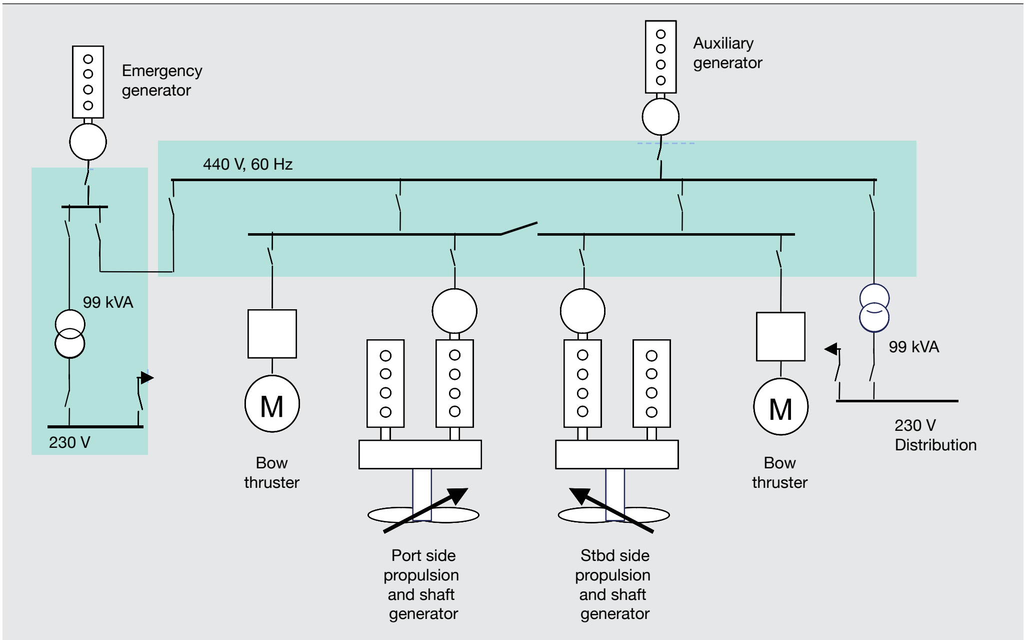
Electric propulsion makes it possible to increase energy efficiency by running the propellers at variable speeds to reduce hydrodynamic losses, as well as optimizing the power plant configuration and operation to ensure a closer to the best possible working condition for the diesel engine prime movers.

Until recently, nearly all anchor handling tug supply (AHTS) vessels were built with diesel-mechanical propulsion due to an overriding focus on bollard pull requirements, even though their operational profile made them even more suitable candidates for electric propulsion, compared with OSVs. For smaller AHTS vessels, there are few reasons for not selecting electric propulsion. However, higher investments demanded by this solution make such a commitment more challenging for shipowners. A parallel hybrid solution may then be a good trade-off, where additional building costs are lower, while some of the important fuel-saving characteristics of diesel electric propulsion are accrued.

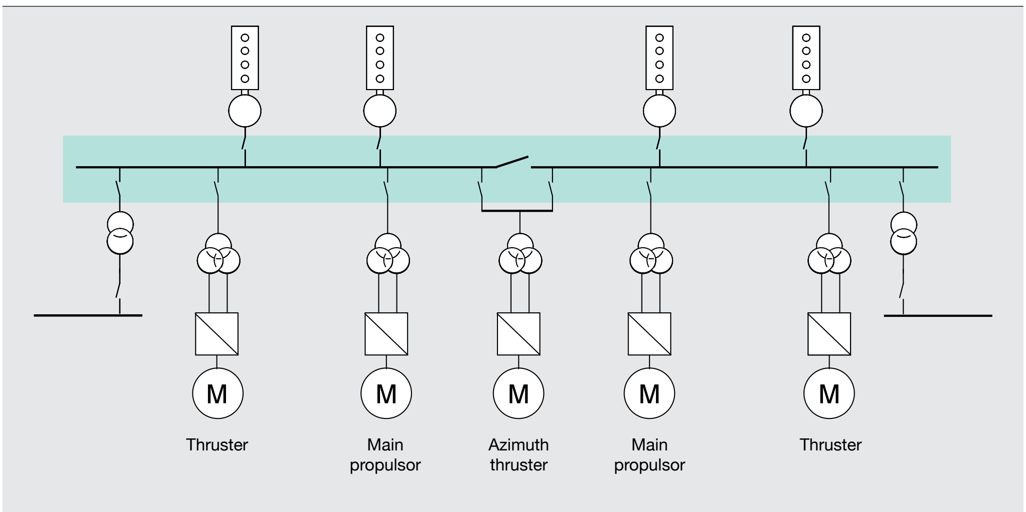
Energy efficiency of electric propulsion

Electric propulsion has demonstrated substantial fuel reduction, compared with direct mechanical propulsion in OSVs (Figure 1). The fuel savings will often reach 15- 25 percent in typical operating profiles and as much as 40-50 percent in pure DP operations. As a result of this, together with an increasing awareness on operational costs and environmental emissions, a large part of the OSV fleet is now specified by the oil companies and charterers to be equipped with electric propulsion.

1a Conventional direct mechanical propulsion



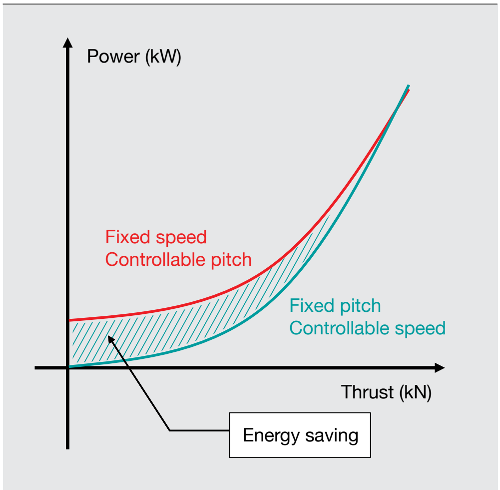
1b Electric propulsion



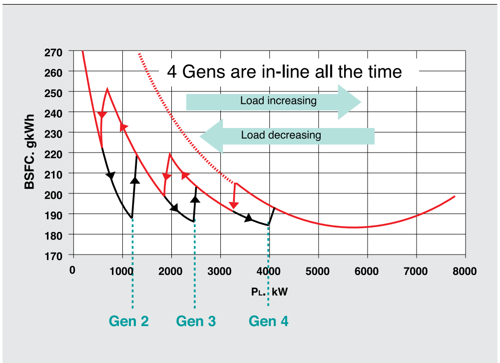
Reduced fuel consumption in an electric propulsion system can be attributed to two key elements. The first is the variable speed control of the propeller, which reduces the "no-load" losses of the propellers to a minimum compared with classical fixed-speed controllable-pitch propellers. The second element is the automatic start and stop of the diesel engines, which ensures that the engine load is kept as close to its optimum operating point as possible, within the limits of operation.

The classical design of an offshore support vessel, including an AHTS vessel, uses fixed-speed propellers with controllable pitch. Compared with

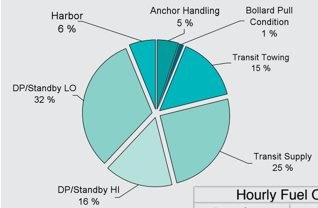
2 Comparison of shaft power versus provided thrust from a fixed-speed controllable pitch propeller (CPP) and a variable speed fixed-pitch propeller (FPP)



3 Fuel consumption per kWh of produced energy

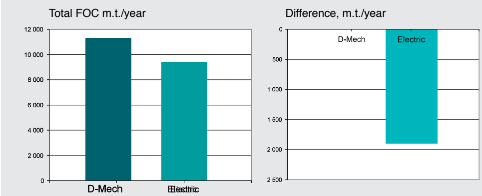


4 Impact of ratio of station keeping mode versus transit mode in fuel saving of diesel electric systems, this is for illustration and not calculated for a particular case



	Hourly Fuel Oil Comsuption kg/h		
	Base Case D-Mech	Electric Propulsion	Operation Profile
Anchor handling	2280	2295	438
Bollard Pull Condition	2451	2795	88
Transit Towing	1898	2053	1314
Transit Supply	1276	1036	2190
DP/Standby HI	1377	1020	1402
DP/Standby LO	1015	620	2803
Harbor	26	25	526

Total FOC kr//year	11 293 005	9 396 661	
Total FOC m.t./year	11293	9 397	
Difference, m.t./year	0	1896	



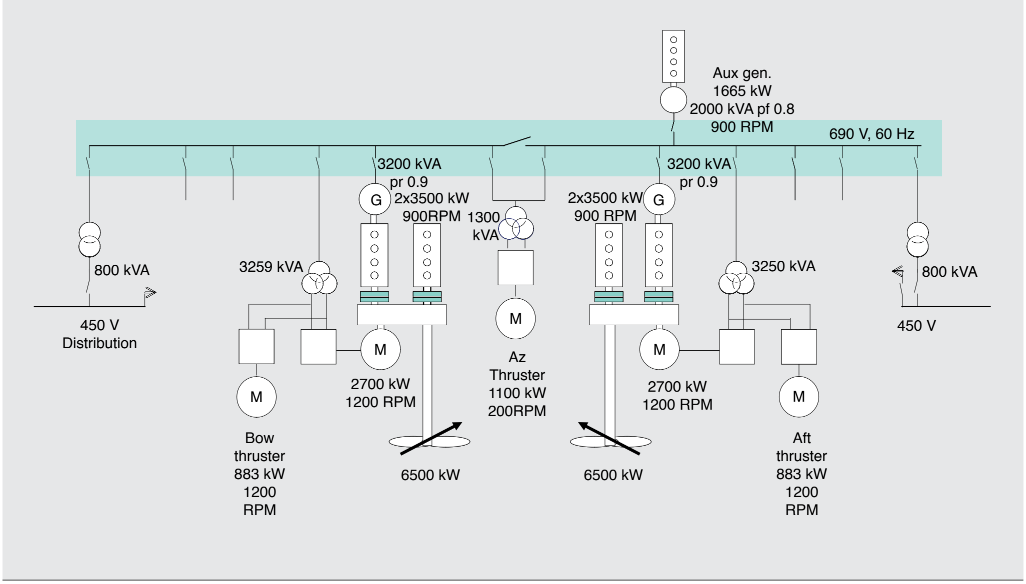
variable-speed control of the propeller, this is a very inefficient way of controlling the thrust due to the high “no-load” losses of the fixed speed propellers (Figure 2). This alone contributes to most of the savings in electric propulsion when applied to offshore vessels. In addition, the utilization of the thruster capacity in DP operations is very low for most of the days operational in, for example, the North Sea, even though this is regarded as a harsh environment.

Electric propulsion also offers the potential for the optimal loading of the diesel engines by using a number of smaller engines, compared with using a smaller number of larger units. Depending on the load, the automatic start and stop of the engines yields better loading and thus reduces fuel consumption (Figure 3).

This reduction in fuel consumption is to some extent counteracted by the higher losses in the transmission system between the diesel engines and the propellers. While losses in the shaft line and gear box of a conventional design are of the order of a few percent, transmission losses in a diesel electric system are in the range of 8-11 percent depending on the concept and efficiency of the components in the drive train. Hence, the potential for fuel savings is highest for vessels with an operational profile where much of the time is spent in DP, standby or manoeuvring, while the benefits are less obvious, absent, or even negative where transit at high speed is the dominating operational mode (Figure 4).

The same mechanisms for energy efficiency and fuel savings that are proven in the OSV segment are available for AHTS vessels; in fact, they are more compelling. In an anchor handler, the peak power is determined by the bollard pull requirement for the vessel, which in most cases will be further from the average load point the higher the bollard pull is. A calculated case study shows that for a 200+ metric ton bollard pull AHTS vessel, fuel consumption will be 1,900 metric tons lower when electric propulsion is used (Figure 5).

5 Electric propulsion and direct mechanical propulsion for a 200+ metric ton bollard pull AHTS



Although there is an increasing interest in using electric propulsion for AHTS vessels, most anchor handlers are today built with conventional diesel-mechanic solutions in spite of the obvious fuel saving potential. Contributory may be that charterers awareness of the fuel costs is lower in this segment, and the focus on fulfilling the bollard pull requirement is higher. In addition, as propulsion power increases, so do extra investment costs, which may prevent designers and owners from promoting electric propulsion if they do not get their rightful portion of savings available.

An alternative to the full electric solution is the combination of mechanical and electric propulsion systems – the so-called hybrid propulsion system (Figure 6). As the electric and mechanical propulsion systems work in parallel through the gear box, this is also called "parallel hybrid."

In terms of installation costs, hybrid solutions are more economical than pure electric solutions. In principle, the hybrid solution will gain most of the same benefits in energy efficiency in low load operations, due to the variable speed thrusters and optimal diesel engine operations and at the same time reduce the transmission losses at peak propulsion loads. For these reasons, several new AHTS vessel designs have been based on such hybrid solutions, especially those with high bollard pull.

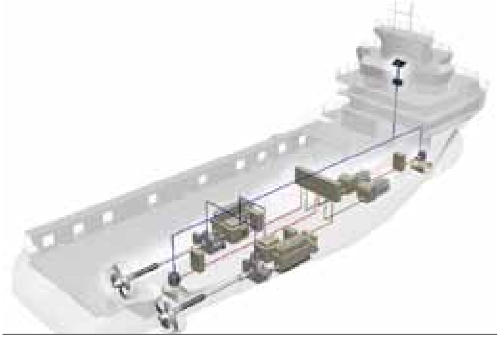
However, the increased mechanical complexity of such hybrid systems – where the crew must be more active and manually select the optimum operational modes for the prevailing conditions – should not be disregarded. In pure electric propulsion systems, it is much easier for the power management system to optimize the configuration of the power automatically and gain a reduction in consumption of fuel and lower environmental emissions, especially NO_x and CO_2. With the adoption of electric propulsion by OSVs and now also by AHTS vessels, fuel consumption, emissions and operational costs are being drastically reduced.

Electric propulsion systems make fuel savings possible through the flexible operation of the vessel, even though the system itself introduces new losses in the energy chain. Efforts can, of course, be made to reduce these new losses, but in order to maximize the benefits of electric propulsion, the focus should primarily be on designing a simple, reliable and flexible system.

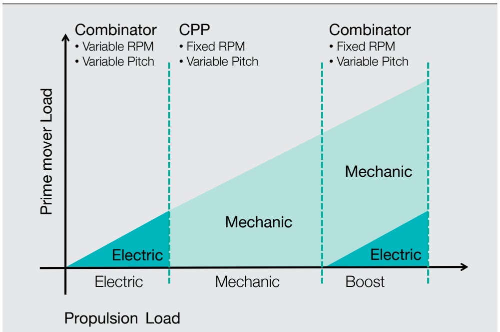
Control of parallel hybrid propulsion

As the design is optimized for the ship's operationing profiles and owner's requests, the control of the parallel hybrid propulsion must also be considered case by case. But in principle, the vessel can be operated in three ways:

6 Hybrid electric and mechanical propulsion for an AHTS



7 One approach to control a parallel hybrid propulsion system



8 The 423 metric ton bollard pull vessel *Far Samson* with hybrid propulsion system; diesel mech: 4 x 6000 kW (4 x 8160 BHP) and diesel electrical 4 x 2755 kW. Total propulsion power: 35900 BHP on main propellers

– Pure electric propulsion for low-speed manoeuvring, transit and DP
– Pure mechanical propulsion for tug operations and high-speed transit
– Hybrid electric and mechanical propulsion, where electrical equipment can be used as a booster for the mechanical propulsion system to maximize bollard pull

One approach, which utilizes all three modes, is shown in Figure 7.

ABB's electric propulsion offerings

As the leading supplier of electric propulsion, ABB designs and offers a wide range of electric or hybrid solutions, with or without energy storage. The concepts shown above feature classical fixed-system frequency AC distribution. However, the concept of Onboard DC Grid is well suited both in the pure diesel electric configuration, as well as in parallel hybrid solutions.

From 2077 onwards and as per May 2012, ABB has supplied electrical solutions for 26 vessels with hybrid propulsion, including 24 anchor handling vessels. The total installed propulsion power in each of these ranges from 14 to 24 MW.

The largest hybrid propulsion power delivered so far has been for Farstad Shipping ASA, for the vessel *Far Samson*, delivered in 2009.

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