Game-changing permanent magnet solutions

Soaring fuel prices, global overcapacity and lower profit margins are opening the way for advanced technologies that revolutionize the way ships generate and use energy

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Next-generation hybrid propulsion systems from WE Tech and The Switch, a pair of Finnish companies, are game changers in their own right when it comes to reaching the highest energy efficiency, lowering the costs of operation and helping to comply with future environmental legislations. Solutions such as these enable ships to stay afloat and profit in a sea of fierce competition.

Best of both worlds

The shaft generator has been successfully used on board ships for the past 30 years. The main benefit of adding a shaft generator is to produce electrical power with main engines that have lower fuel consumption and run on cheaper heavy fuel oil, thereby greatly reducing the use of auxiliary generators. The downside, however, is that the propulsion machinery can only be run at constant speed.

The other alternative has been to operate without a shaft generator. In this case, ships continue to take advantage of variable speed operation of the main engine while auxiliary generators produce electricity on board. However, the downside with this method is that the ship operator pays a premium in higher fuel cost, as well as auxiliary generator maintenance costs.

Now merchant vessels can get the best of both approaches by using a game-changing solution that combines the WE Drive variable frequency drive with advanced control and The Switch permanent magnet (PM) technology. This enables vessels to produce electricity with better efficiency for the entire ship's network, lower costs by keeping auxiliary generators off, and allow the main engines to operate at variable speed. In total, it represents major operational savings for vessels with four-stroke, but in particular two-stroke, engines.

Although a newcomer to the shipping industry, PM technology is renowned for its unmatched design flexibility. Thanks to their higher power density, PM machines can be more compact, lighter in weight and smaller in size.

Better efficiency

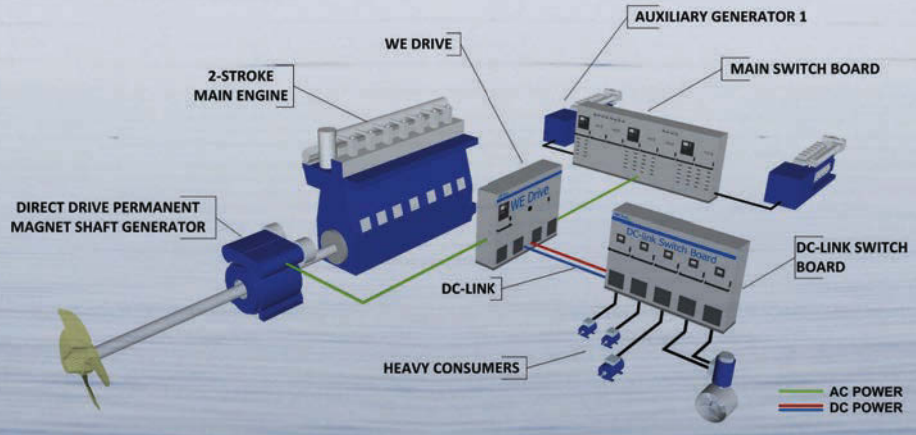
With its active front-end frequency drive technology, the WE Drive allows a shaft generator to operate at variable speed. This enables the propulsion machinery to be operated at its optimal duty point at all times, giving a vessel up to 20% better propulsion machinery efficiency compared with constant speed operation.

The WE Drive variable frequency drive is based on IGBTs with advanced vector control technology and is optimized to work with PM machines for the best overall system efficiency. The WE Drive offers a modular, lightweight design, which is air cooled or liquid cooled, and exceptional thermal management. Flexible active power and torque control ensure smooth operation. The drive incorporates island mode operation, which means it creates the ship's electrical network alone or in continuous parallel operation with auxiliary generators.

Recent hybrid propulsion system vessels using the WE Drive to improve energy efficiency include M/V Miranda and M/V Mistral, owned by Godby Shipping, as well as M/V Bore Sea and M/V Seagard, owned by Bore. These vessels are equipped with four-stroke main engines, and thus have reduction gears with a power take out (PTO) shaft where the shaft generator is connected.

Game-changing solution for hybrid propulsion systems: WE Drive variable frequency drive with The Switch PM technology

- **WE Drive:** air cooled or liquid cooled variable frequency drive
- **The Switch PM machine:** provides unmatched power density, energy efficiency, design flexibility and operational reliability
- **Control:** Dedicated Power Management System (DPMS)
- **Electrical power generation (PTO mode):** generating the ship's electrical network while the main engine is operated at variable speed
- **Take me home/boost mode (PTI mode):** operating the PM machine as a motor for various hybrid operations
- **DC-link:** brings energy efficiency to the entire vessel



The WE Drive system removes the need for constant speed operation by using variable frequency drive technologies in shaft generator systems

PM high power density

PM technology has been proved in numerous industries to provide unmatched power density, energy efficiency, design flexibility and operational reliability. Now these same advantages are available for numerous marine applications.

A synchronous PM machine contains neodymium-iron-boron (NdFeB) magnets, which are materials with a very high flux density, which makes them ideal for variable speed generators throughout the entire speed range. The magnetic field is created with almost zero rotor losses.

A PM machine gives high-efficiency performance over the entire operating range, leading to considerably reduced fuel consumption. A PM machine is typically 2-4% more efficient at full load and 10% more efficient at part loads compared with induction machines. These technical efficiencies result from a lack of current losses in the rotor, the absence of an exciter, and reduced winding losses.

Thanks to the higher power density, the size and weight of a PM machine can be substantially smaller compared with induction machines. This leads to greater flexibility with the limited space available in ship configurations.

PM machines have proved their high reliability and durability under a number of extremely harsh operating conditions in many other industrial applications, such as onshore and offshore wind power. They deliver excellent performance with corrosion resistance and temperature tolerance.

Ideal for merchant vessels

The combination of WE Drive and The Switch PM technology opens up an all-new territory for hybrid propulsion systems, namely the large merchant shipping sector, where two-stroke main engines are the preferred type of prime mover.

Ocean-going merchant vessels are predominantly propelled by fixed pitch propellers that are directly driven from slow-speed two-stroke main engines. Along with being very reliable, the two-stroke main engine is also able to keep fuel consumption at least 20g/kWh lower than in a medium speed four-stroke main engine.

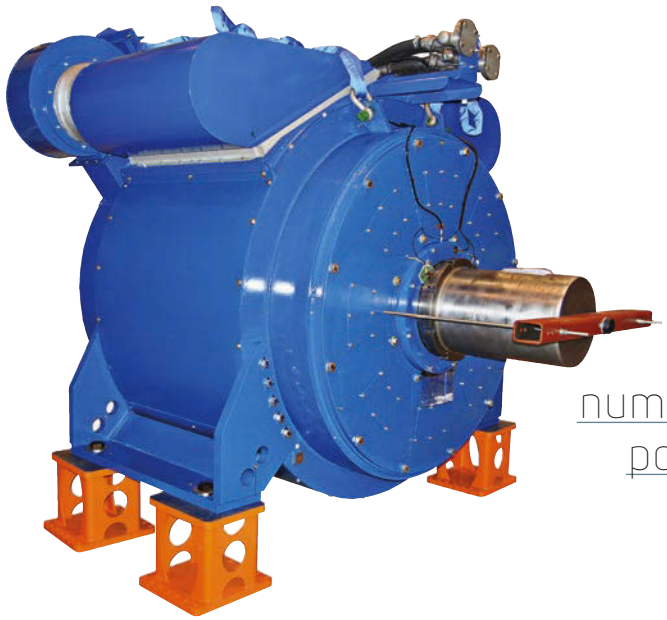
As a merchant vessel is sailing long distances in the deep sea during most of its operating time, fuel economy is the most important factor after safety and reliability. The two-stroke main engine operates at slow speed, equivalent to the required propeller speed, and thus this type of engine is directly connected to the propeller via an intermediate shaft and requires no additional gearing to match the desired propeller speed. This leads to a more straightforward propulsion system with fewer components, and fewer maintenance needs, which translates to a lower cost of operation.

Traditionally, adding a shaft generator to a system like this requires special equipment such as tunnel gears with a step-up PTO shaft for the generator drive. These arrangements add complexity to the system and are fairly costly in the investment phase. This has led, in most cases, to omitting a shaft generator for two-stroke main engine propulsion plants, and relying on auxiliary generators for electricity on board.

A direct-drive PM shaft generator with a variable frequency drive offers the advantages of a hybrid propulsion system to the two-stroke main engine-driven propulsion system.

The mechanical setup of a direct-drive PM shaft generator is remarkably straightforward: the PM rotor is mounted on the intermediate shaft of the propulsion system. Mass and inertia are very low and thus the impact on propulsion system torsional vibration calculations (TVC) remains minimal. No additional bearings are required, thus the propeller shaft system design remains uncompromized. The generator housing, consisting of a compact, foot-mounted stator package, including the rotor and intermediate shaft, is positioned on the generator bed in the propeller shaft line and connected via flanges. Other interfaces such as cooling water pipes and power cabling are handled in a conventional manner.

With the WE Drive and direct-drive PM shaft generator in PTO mode, a ship's electrical power is generated by the fuel-efficient two-stroke main engine. This means that auxiliary generators can be stopped. Electrical power is generated at a rate of 160-170g/kWh from heavy fuel oil, compared with 210-220g/kWh for the more expensive marine diesel oil or marine gas oil that auxiliary generator sets use. As the operating hours of the auxiliary generators therefore remains at some 2,000 hours annually, there will be substantial savings in service and maintenance costs as well.



"PM technology has been proved in numerous industries to provide unmatched power density, energy efficiency, design flexibility and operational reliability"

Above: The Switch's permanent magnet generator offers superior energy efficiency along with decreased motor size and total weight

Below: The WE Drive has been successfully commissioned on board Bore's M/V Seagard

In power take in (PTI) mode, the WE Drive converts auxiliary generator power to propulsion power by employing the direct-drive PM shaft generator as a motor. By using the PTI feature in boost mode, it is possible to design the propulsion machinery with a smaller-sized main engine for normal operating conditions, while using the boost mode in exceptional conditions. With the addition of a mechanical clutch in the propeller shaft line, which enables the two-stroke main engine to be disconnected, the PTI mode can be used as a take me home/take me away feature (operating the PM machine as a motor for various hybrid operations). This provides safe return to port, or enables main engine maintenance within the normal operation schedule.

Multiple application use

PM technology can also be used for other applications, such as auxiliary generators, bow thrusters and winches. When used with auxiliary generators, PM technology can run auxiliary generators at lower speeds when possible, to create savings. This enables a higher energy efficiency and longer auxiliary generator service lifetime. The auxiliary generators can be connected to the DC-link so that the main switchboard can be smaller.

PM technology can also be flexibly integrated with bow thrusters. Shapes vary from a standard, pipe-like form with a small diameter to a custom-made short PM machine with a large diameter that can be optimized for specific tasks and placement on the vessel.

For winch applications, PM technology enables better torque over conventional systems and have a wide speed range, from zero upward. The rugged PM-based solution complies with full torque at zero rpm as specified by duty type S1. This is essential to create constant tension, for instance when a tugboat has to tow a ship in fluctuating conditions such as waves, current or wind. PM technology can withstand extreme temperatures, vibrations and heavy use.

Proven track records

With their own individual proven track records, WE Tech Solutions and The Switch are cooperating to provide this game-changing technology for various kinds of marine applications. WE Tech Solutions has been successfully lowering the cost of ship operations since the company was founded at the start of 2010. Renewable energy applications that are based on PM technology from The Switch have also been proved successful in extremely harsh operating conditions, such as onshore and offshore wind power, where the company has an installed capacity of over 6.5GW.

Together, the companies can provide ship designers and builders with turnkey deliveries for the most energy-efficient operation in the challenging marine environment. Additional services include design consultation for selectivity, project management, and the capability to deliver integrated solutions for new build ships or upgrades of existing fleets.