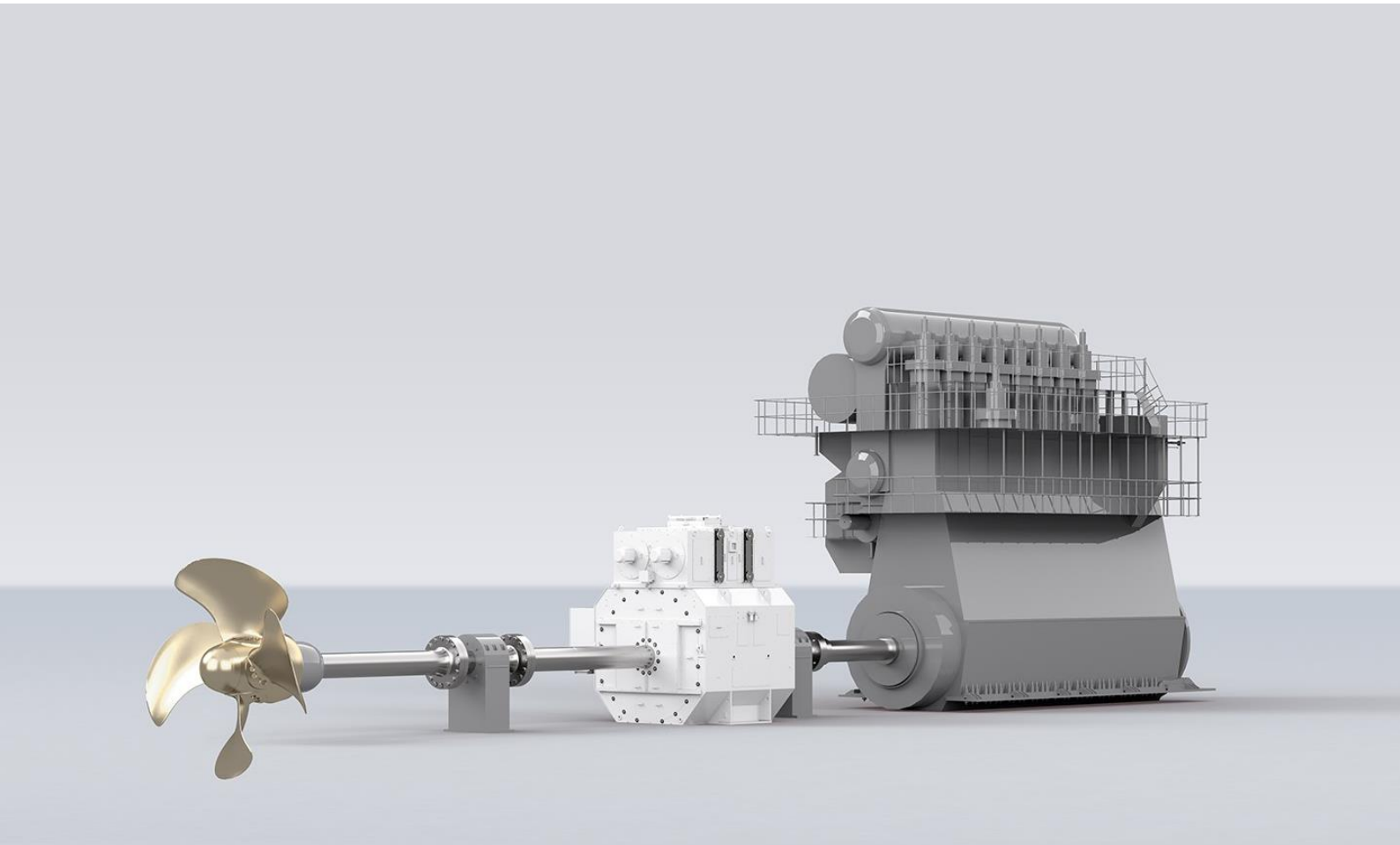
WHITE PAPER

Towards an energy efficient future for shipping

High efficiency ABB permanent magnet shaft generator solutions



Meeting emissions reduction targets

ABB's high efficiency shaft generator solutions use proven permanent magnet (PM) technology to save fuel, cut emissions and reduce operating and maintenance costs. They are a reliable and safe solution to help the shipping industry comply with emissions reduction targets and build a more sustainable future.

Strong industry response to climate change

Fast population growth, rising demand for consumer products, and globalization have led to rapidly increasing volumes of goods being shipped around the world. According to the OECD, ocean shipping carries around 90% of traded goods and volumes are set to triple by 2050. At the same time, shipping accounts for 2.6% of total greenhouse gas (GHG) emissions, and without any countermeasures this figure will also triple by 2050.[1]

Faced with the accelerating rate of climate change, governments and organizations worldwide have introduced measures to reduce GHG emissions. For its part, the International Maritime Organization (IMO) has brought in mandatory measures to improve the energy efficiency of the world's ships. The IMO's goal is to reduce total annual GHG emissions from international shipping by at least 50% by 2050 (compared to 2008 levels), with the ultimate aim of phasing them out completely.[2]

...By 2050

Shipping trades

GHG emission

x3

Strong industry response to climate change

CO_2 emission reduction
To meet EEDI and EEXI set by IMO
also helps raise your CII rating

- EEDI (Energy Efficiency Design Index)
- EEXI (Energy Efficiency Existing Ship Index)
- IMO (International Maritime Organization)
- CII (Carbon Intensity Indicator)

[1] www.oecd.org

[2] www.imo.org

Increasing efficiency requirements

The IMO's Energy Efficiency Design Index (EEDI) applies to new ships, with the Energy Efficiency Existing Ship Index (EEXI) targeting existing vessels. Maximum threshold levels have been set for carbon dioxide emissions for transport work (for example, grams of CO_2 per ton-mile), and each vessel's EEDI or EEXI figure must fall below the relevant maximum. The requirements are tightened every five years in order to promote continued technical development.[3]

Ship owners, shipbuilders, marine systems integrators and OEMs are looking at various technologies to ensure that vessels – both existing and newbuild - will comply with the increasing requirements. Shaft generators represent a proven and well-established solution, which permanent magnet technology takes to the next level in terms of efficiency and emissions reduction. They are already fully available and are easy to integrate into existing and newbuild vessels.

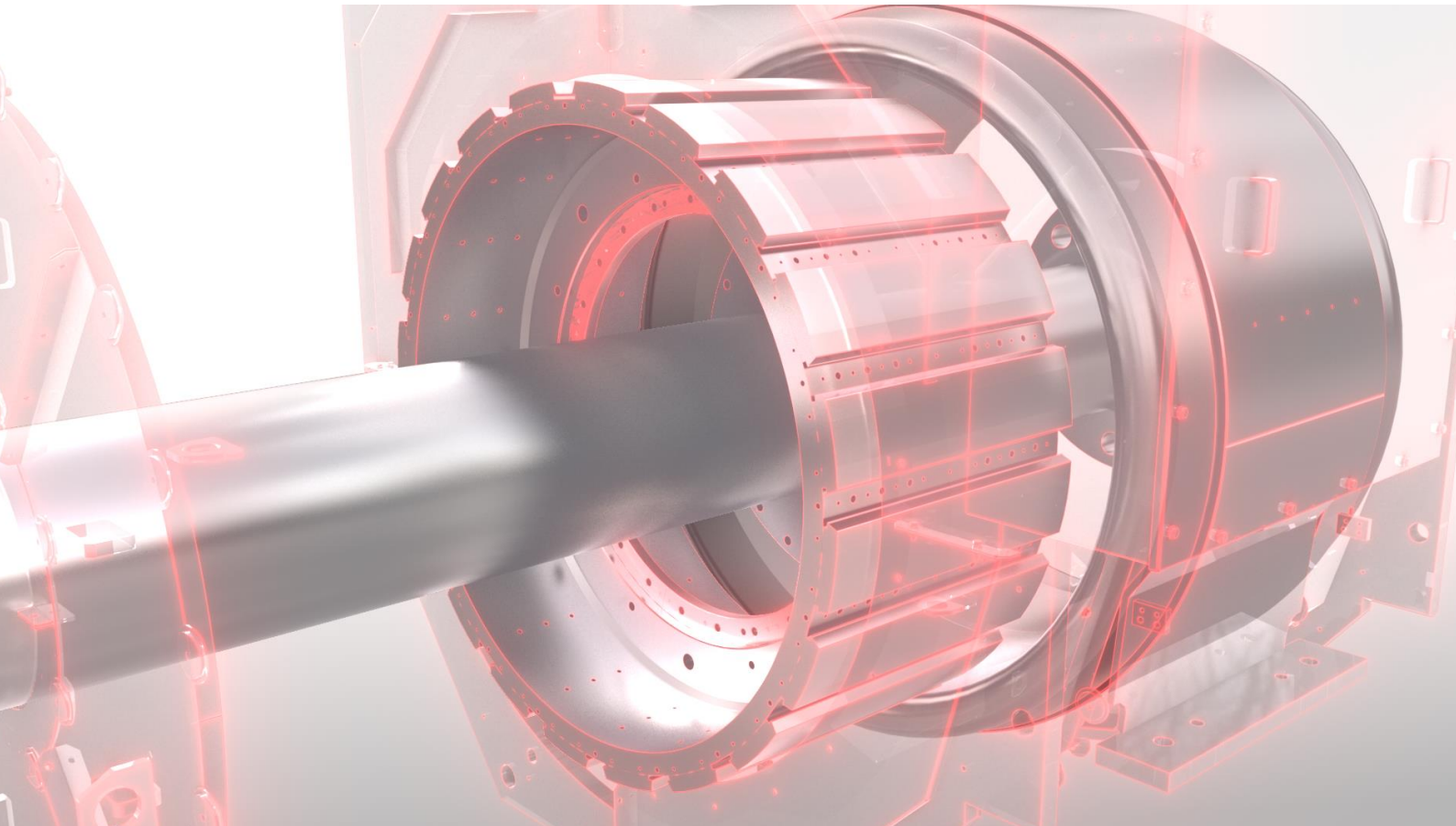
[3] www.imo.org

Backed by more than 130 years of experience

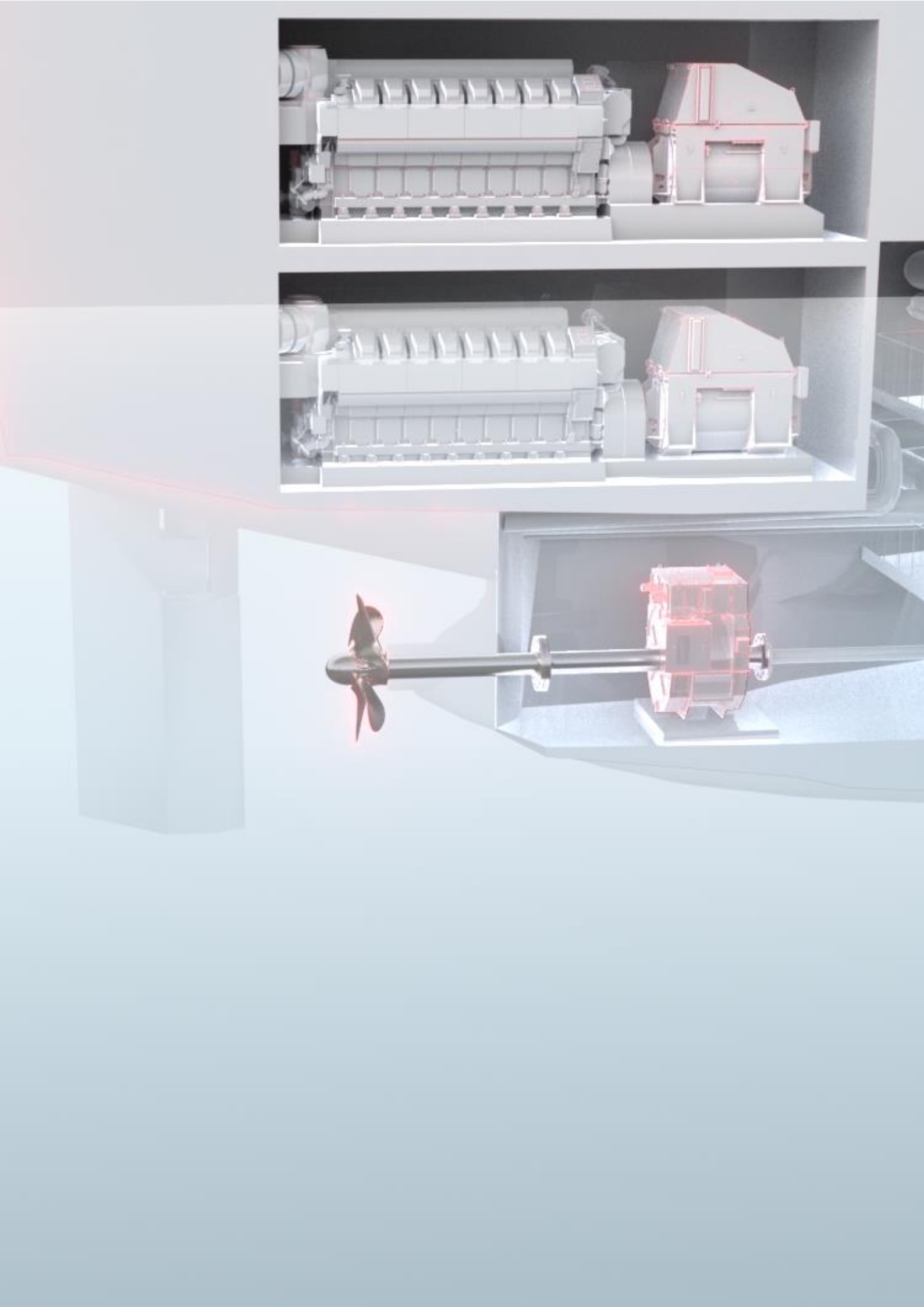
ABB and its predecessors have been manufacturing motors and generators for more than 130 years. The marine industry is a particularly important customer sector, with over 1,000 high voltage marine generators supplied in the last 25 years alone.

In 1990 – when permanent magnet materials first started to become commercially viable - ABB launched its pioneering PM technology projects. Building on this early work, it has established itself as the premier global manufacturer of large PM motors and generators. It supplied its first PM propulsors for ships in 2001, with powers ranging up to 5 MW. Since then, it has become the leading supplier of PM marine propulsion motors up to 14.5 MW, with more than 200 already manufactured.

Additionally, ABB has extensive experience in supplying large megawatt-class PM generators for offshore wind turbines. In total, it has supplied around 500 large PM motors and generators for marine and wind turbine applications. These machines have nominal torque ratings in the range 200 – 1,000 kNm, and above. Overall, the installed base of large ABB permanent magnet machines has accumulated more than 4,000 years of operation.



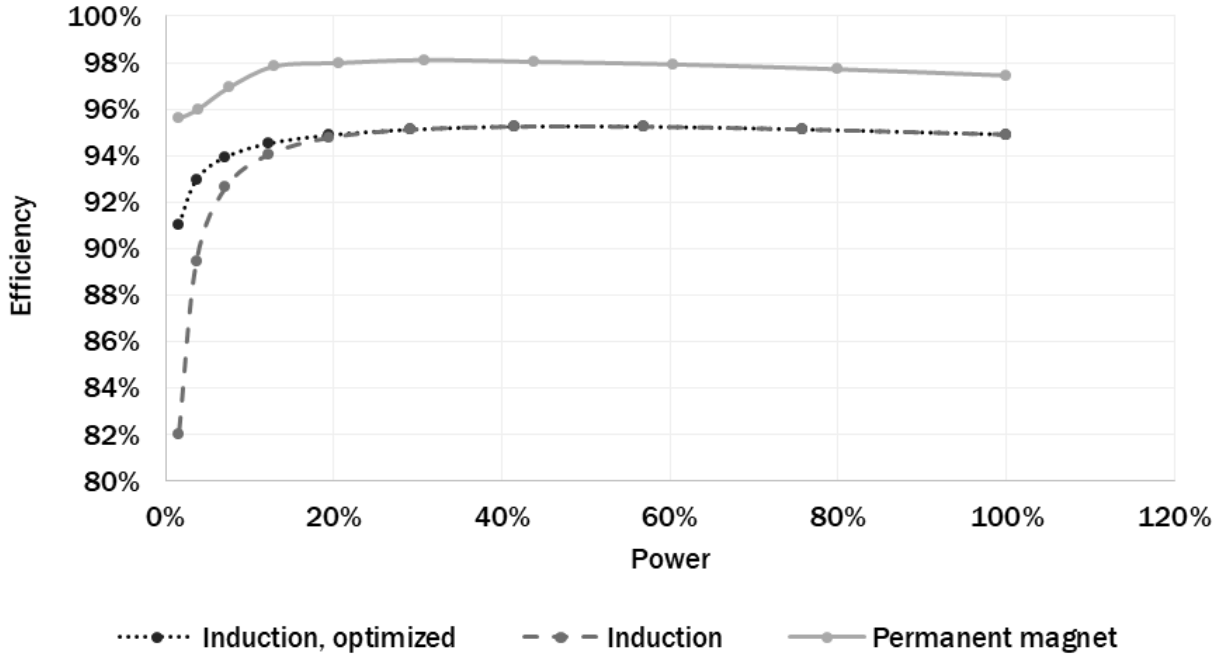
Main specifications	
Operating modes	PTO/PTI/PTH with full converter
Rated power	1000 - 4000 kW
Base speed	30 - 80 rpm (typical)
Torque	175 – 575 kNm
Voltage	400 - 690 V (extendable to high voltage on request)
Enclosure	IP 44, up to IP 54 on request
High efficiency, even at low speed and partial load operation	
Small footprint, better power/size and power/weight ratio	
Redundant cooling with a water jacket and heat exchanger	
Simple and reliable rotor geometry	
Designed according to IEC 60034 and relevant major classification society requirements	



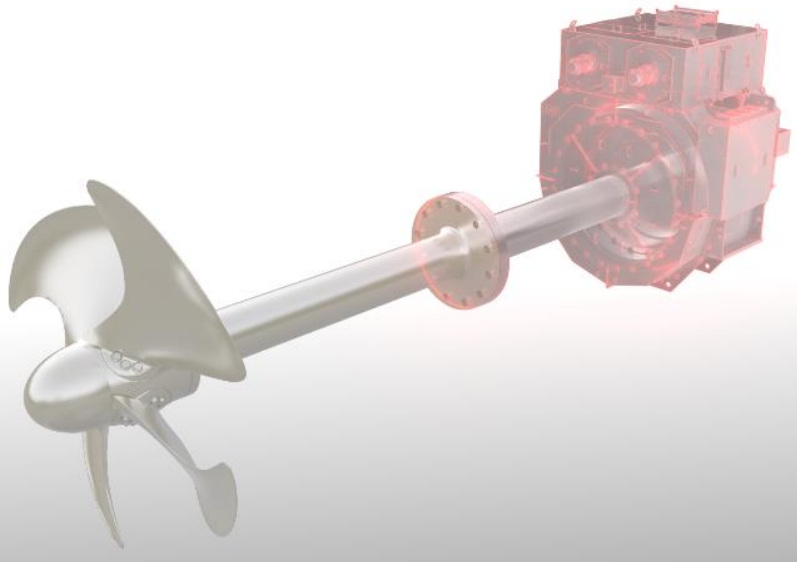
Industry leading technology

Superior efficiency

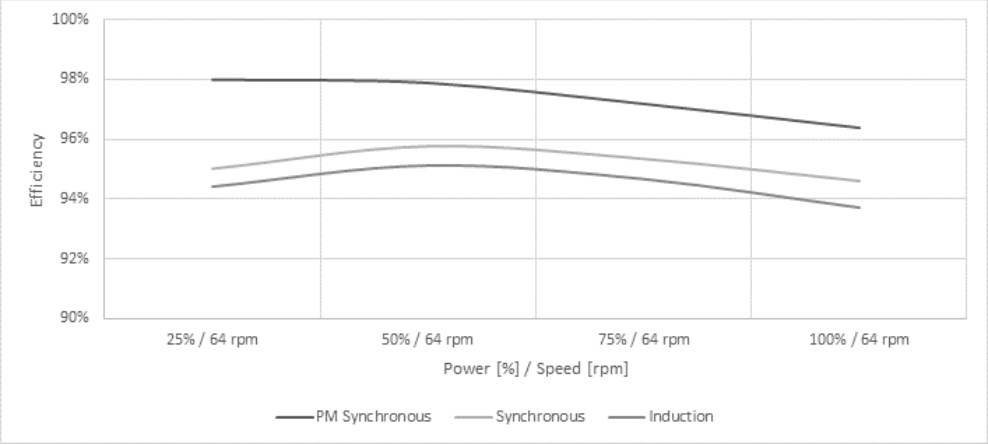
PM generators are more efficient than induction and synchronous generators due to their lower electrical losses. The efficiency difference is significant at full load, and it becomes even greater when operating at partial load. Compared to induction generators, PM generators have minimal losses in the rotor and lower winding losses in the stator. Unlike synchronous generators, they do not need an excitation supply and therefore avoid most of the losses that occur in externally excited synchronous rotors.



Permanent magnet generators are more efficient than induction generators at all power levels.



Example case 3000 kW, 16 - 80 rpm



PM technology is more efficient than synchronous and induction technology across the entire speed range (theoretical comparison).

Straightforward, robust construction

Over the last thirty years ABB has built unrivalled expertise in PM solutions. It applies its magnetic circuit know-how to maximize the efficiency and reliability of the magnet modules and rotor. The rotor geometry is straightforward and robust, consisting of the rotor ring, magnets and support structure. The simple construction with fewer components ensures that maintenance needs are minimized.

Extensive patents

The permanent magnet module and fixing method with adhesive bonding and mechanical mounting have been patented by ABB. The design resists fatigue loads and the magnets are securely fastened. The modules have been developed to provide optimal corrosion protection for the magnets.

The use of surface-mounted magnets results in low magnet and overall rotor weight, which is especially important in larger generators. This reduces the amount of rare earth material needed in the generators. The magnets are manufactured from neodymium-iron-boron (NdFeB), a compound that has an extremely high magnetic flux density. Long-term supply contracts ensure that ABB will have continued access to this material.

Short-circuit withstand

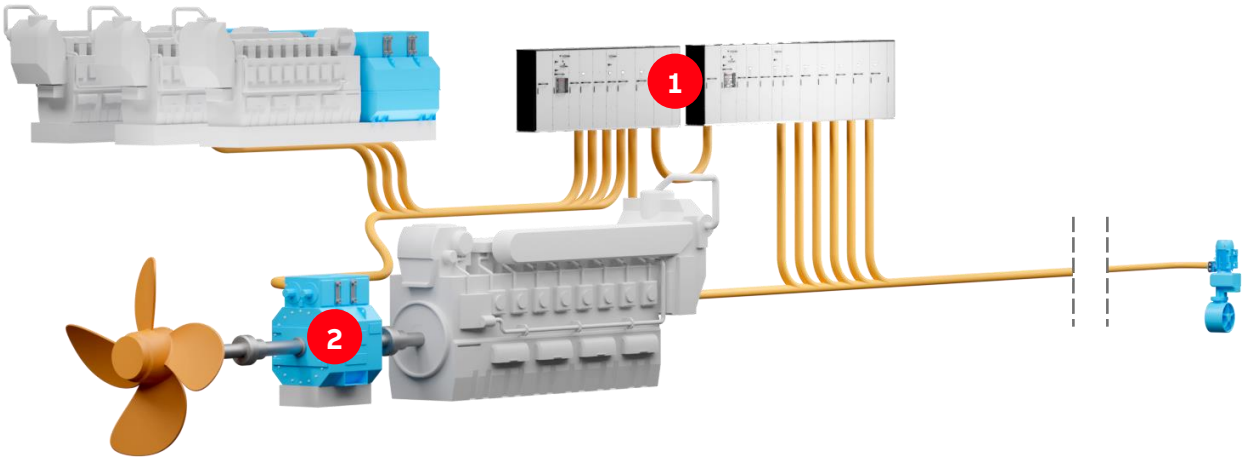
The magnet modules can withstand a direct short circuit at the rated temperature without demagnetization. They are also designed to minimize cogging torque – which is created by the interaction of the permanent magnets in the rotor with the stator slots – in order to maintain excellent reliability.

The stator windings feature ABB's MICADUR® Compact Industry insulation system, which is based on the vacuum pressure impregnation (VPI) method. This has been proven in tens of thousands of large ABB motors and generators that are operating all over the world.

Patented ABB permanent magnet rotor technology has proven short-circuit withstand without demagnetization.

Variable speed operation boosts efficiency

In the past, shaft generators relied on constant speed operation of the main engine to deliver a fixed frequency to the grid. However, this is not very efficient at partial loads – where most vessels spend a high proportion of their operating time – as both the propeller and engine are less efficient when running at low loads but high rpm. Adding a variable speed drive (VSD) enables the propulsion plant to operate at the most efficient speed / propeller pitch combination.



1 Variable Speed Drives (VSD)

2 Permanent Magnet Shaft Generator

Big fuel savings

A VSD enables more efficient operation of the engine and propeller. With controllable pitch propellers (CPP propulsion), a VSD allows efficient use of the combinator mode, which reduces propeller losses significantly when the propeller is operating at partial load. Variable speed operation can achieve fuel savings as high as 40% or more compared to fixed speed (direct-on-line) running.

Clean power for the ship’s grid

The VSD takes the power produced by the shaft generator and converts it into sinusoidal constant frequency AC power for use in the ship’s grid. It can feed a DC grid if the main power transmission on board is based on DC. The VSD is also able to compensate for unbalanced loads in the grid and provide reactive power compensation. Total voltage harmonics are very low – even down to less than 2% in some cases.

To ensure full compatibility of the electrical systems, ABB PM shaft generators are optimized for use with ABB VSDs. The generators’ high power factor enables use of a smaller drive with a lower current (kVA) rating. ABB VSDs supplied for PM shaft generators incorporate software specially developed for controlling permanent magnet equipment, ensuring fast and precise response.

ABB VSDs are compact, robust, and designed for reliability in harsh conditions. Versions are available that do not require an electrical room for installation.

Saving fuel, reducing emissions and cutting costs

Utilizing the efficient main engine

In almost all cases, producing power with a shaft generator rather than gensets will reduce the vessel's overall fuel consumption. This is because the shaft generator – whether fixed or variable speed - is driven by the vessel's larger main engine, which is generally more efficient than the smaller engines that power gensets. Operating a shaft generator is an effective use of the main engine's power reserve.

Partial load efficiency

Operating the propeller at a lower rpm typically results in a lower power requirement to achieve the same vessel speed. When an ABB PM shaft generator is paired with a VSD to provide variable speed operation, fuel consumption can be reduced at partial loads. The main engine can be run at a more favorable operating point, reducing its specific fuel consumption. This, in turn, reduces emissions of carbon dioxide (CO_2) and nitrogen oxides (NO_x). ABB PM shaft generators are ideally suited for operating at lower rpm: they are engineered for negligible magnetization losses, which means that their efficiency remains high even when running at low speeds and partial load.

Less need for auxiliary generators

A vessel with a shaft generator requires less installed genset power, which reduces capital expenditures (CAPEX). Using the shaft generator rather than auxiliary gensets to produce power is not only more efficient but it also avoids increasing the gensets' running hours. The gensets need less servicing, which brings down maintenance costs and saves on operating expenses (OPEX).

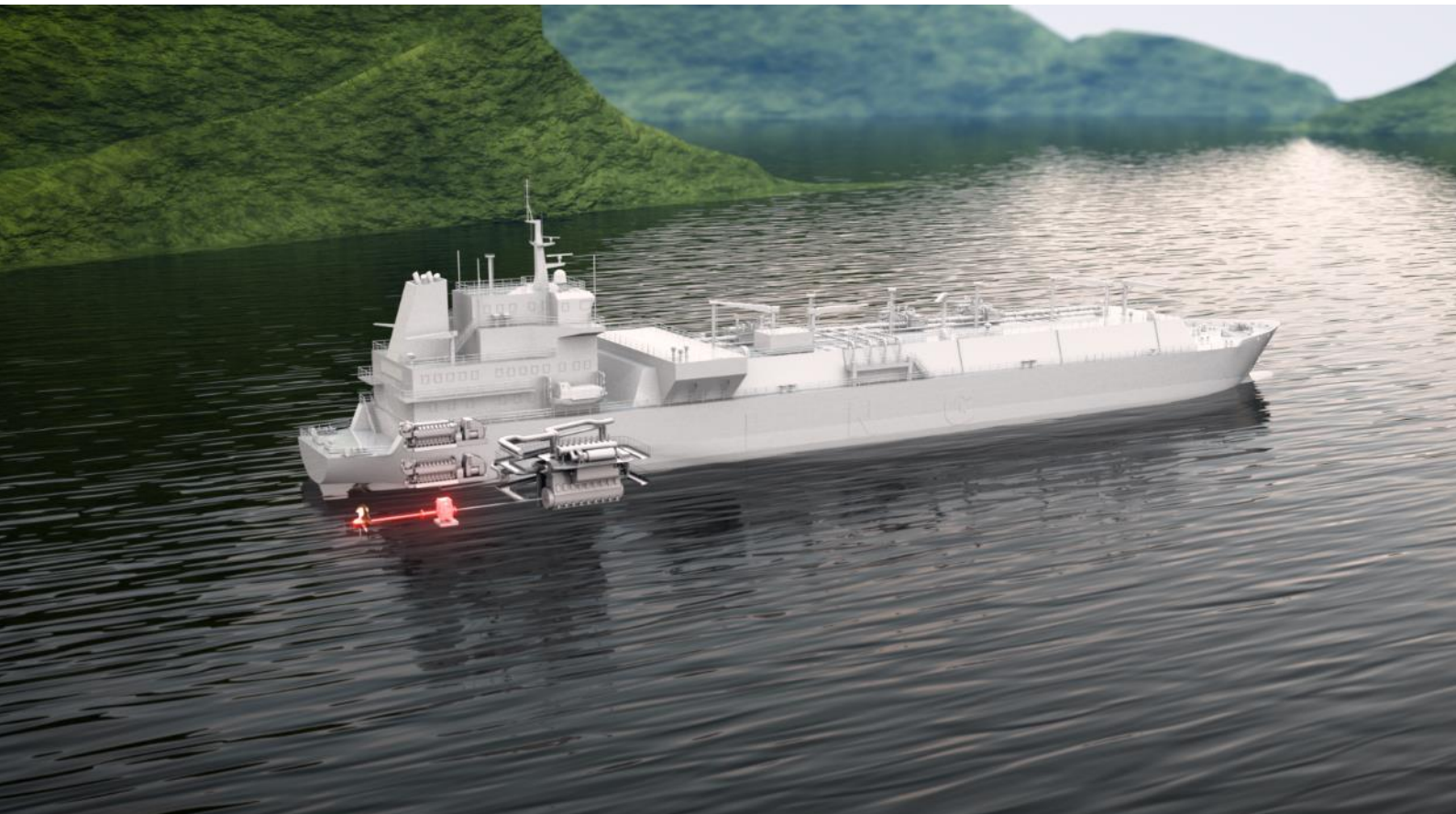
Downsizing the main engine

The main engine in many vessels is oversized. This is because vessels are normally designed for the ‘worst-case scenario’, even though such conditions occur only very rarely. As a result, the oversized main engine will run on relatively low (sub-optimal) load most of the time. This results in higher fuel consumption than necessary for the actual work the engine is doing.

A shaft generator with Power Take In capability can provide additional power to the propeller shaft to supplement the main engine. This type of generator makes it possible for the vessel to have a smaller main engine that operates at its optimal power level for the majority of the time. On the rare occasions that a power boost is needed, gensets are run to power the shaft generator as a motor. The smaller main engine results in lower CAPEX, and fuel consumption is improved because the engine is running at a more favorable load point for a greater proportion of its total operational time.

Lower maintenance requirements

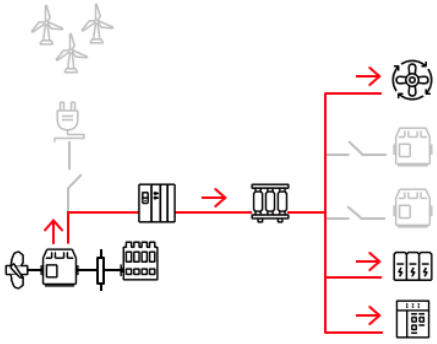
Some conventional synchronous shaft generators use carbon brushes, which are wearing components that have to be replaced regularly. These maintenance costs are avoided with PM shaft generators.



Operational flexibility, redundancy and safety

ABB PM shaft generator solutions offer great flexibility and functionality, and they help to future-proof vessels for new energy sources and propulsion systems. The solutions can be designed to enable the following operating modes:

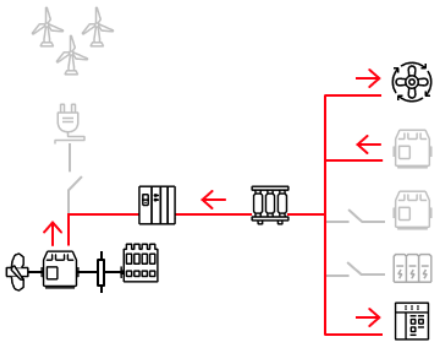
Power Take Off (PTO)



PTO or generator mode uses the energy efficient main engine to produce power. The generator and VSD can be supplied to operate in:

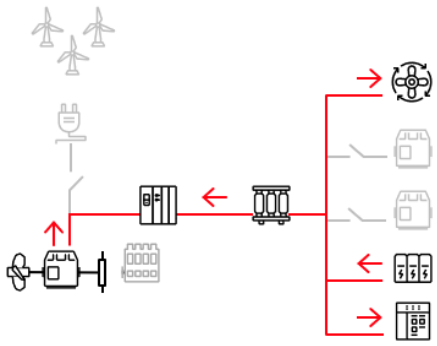
- Island mode, where the shaft generator forms the ship's grid.
- Parallel mode, where the shaft generator operates with other generators or an energy storage system (ESS). In parallel operation with other generators the VSD is configured to use droop control to regulate voltage and frequency.
- Maneuvering mode, where the shaft generator supplies power to a thruster. The VSD is configured so that its power unit functions as a frequency converter and is connected to the thruster motor.

Power Take In (PTI)



The shaft generator acts as a motor, delivering a power boost to the main propulsion shaft. Its power feed comes from the vessel's main grid, either from gensets or an ESS such as a battery. PTI is intended to cover peak power or 'worst-case scenario' needs, such as situations where the vessel has to make up for delays, or cope with heavy weather or ice conditions. In PTI operation the VSD controls the ramp-up and ramp-down of the shaft generator / motor when starting or stopping, reducing mechanical stress and lowering maintenance requirements.

Power Take Home (PTH)



The shaft generator is the vessel's main source of propulsion. This is intended for emergency or short-term use: it enables the vessel to return safely to port when the main engine is out of operation. The PTH function provides redundancy and safety. The shaft has to be fitted with a clutch to enable disconnection of the main engine when PTH mode is activated. In PTH mode the VSD controls the shaft generator / motor with input from the propulsion system.

All-electric operation

Vessels with PTH capability can have an ESS such as a battery installed to allow for all-electric operation in low load conditions. Typical situations where this could be used are slow transit or maneuvering in ports. All-electric operation is very useful in sensitive areas where exhaust emissions and noise pollution are regulated or should be avoided. It is also more efficient than having the large main engine running at very low load.

Shore power connection

ABB shaft generator VSDs can be engineered to operate as a shore power converter. This enables the vessel to connect to shore power instead of using its gensets, with the VSD forming the necessary interface between the shore and vessel grids. When the vessel is in port, a shore power connection is a cost-effective and environmentally friendly way of supplying the hotel load and charging the ESS. It eliminates local emissions and noise pollution in sensitive ports. Having the VSD double as a converter for the shore power connection means savings in space and weight, and it reduces CAPEX.

Compact, light and easy to install

ABB PM shaft generators can be built into new vessels and retrofitted in existing ships, enabling ship owners to improve the efficiency and emissions performance of their entire fleet.

Up to 30% lighter

Thanks to their high efficiency, ABB PM shaft generators have better power/size and power/weight ratios than conventional products. They are 10 – 30% lighter and around 20% smaller than the equivalent synchronous and induction generators. This enables the size and weight of shaft line to be reduced, resulting in CAPEX savings.

Short delivery lead times

ABB’s streamlined systems ensure fast processing from original quotation through order to delivery. Standardized product platforms enable reliable, cost-efficient generators with 30 - 50% shorter delivery lead times than conventional engineered solutions.

All ABB PM shaft generators undergo Factory Acceptance Testing (FAT) before they are shipped. The first generator in a series is subjected to a 13-point type test. Testing is conducted using a test shaft and bearings, and, unless otherwise specified, a test field VSD. Subsequent generators in the series are put through a five-point routine test, in addition to separate testing of the stator and poles in the factory. Online FAT testing is available for ABB PM shaft generators.

Straightforward installation procedure

Once the generator has arrived at the shipyard, ABB’s straightforward, innovative five-step assembly and installation procedure can be put into practice. No special tools are needed. The generator is lifted and supported by the shaft, and the shaft flange is simply secured to the permanent magnet rotor with fixing bolts.

ABB PM shaft generators provide flexibility in configuring the main connections: they can be supplied with an integrated terminal space at the end, or one or two main terminal boxes on the left or right, or both sides. This helps with the cable routing and electrical connections. The generators also have their own built-in cooling system, consisting of a water jacket and heat exchanger, which offers effective and redundant cooling.

ABB’s global manufacturing footprint ensures that it can meet local content requirements from factories covering Europe, Asia and the Americas. The ABB global service network delivers effective local support worldwide.