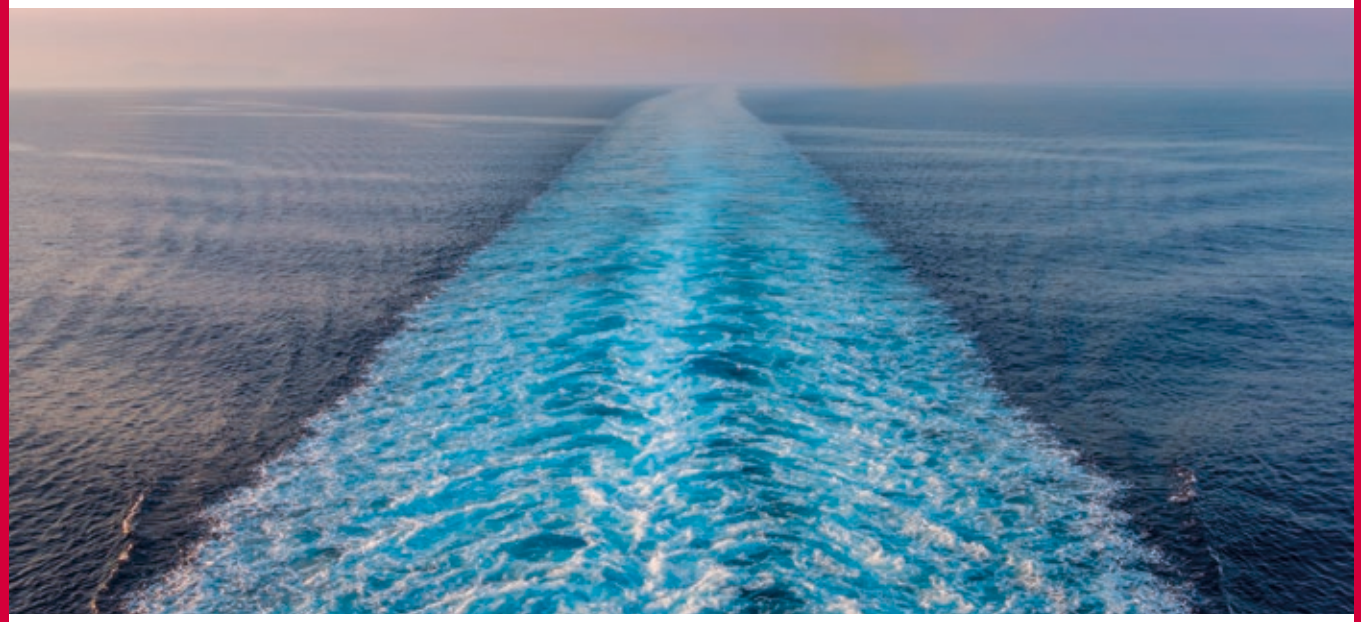
INGEDRIVE H

PTI/PTO Hybrid Electrical Drives



Ingeteam

Ingeteam is a leading company specialising in power and control electronics.

With more than 3500 employees, the company operates globally in Europe, the Americas, Asia, Australia and Africa. Ingeteam's business is built upon the foundations of R&D, to which it dedicates around 7% of its annual turnover.

Climate change and its consequences are currently of great concern. Acceptable limits in terms of harmful gas emissions from combustion engines are increasingly demanding in the maritime transportation sector. Furthermore, in a highly competitive market, it is necessary to reduce the operating costs of vessels where fuel consumption represents a big part of them.

Hence, in our strong commitment to the environment, Ingeteam is actively working on solutions that reduce both fuel consumption and gas emissions that are harmful for health and the environment. Both variables are currently very important in the design of new integrated propulsion systems in vessels.

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Hybrid Propulsion in Vessels

The hybrid topology consists of combining mechanical and electrical propulsion in the kinematic drivetrain. Hence, propulsion efficiency is optimised, and at the same time, responding to a variable power demand quickly and flexibly.

In a conventional, fixed-speed shaft generator system, the shaft generator, powered by the main diesel engine, is used to produce the electrical power for the vessel´s grid.

The diesel engine in turn moves the vessel's main propeller. Therefore, the vessel's grid frequency is closely linked to the propeller's rotational speed. Consequently, the diesel engine's speed must be kept constant to maintain the grid frequency.

The desired vessel speed is only controlled using the propeller's pitch, which means that more energy is often consumed than is necessary, subsequently decreasing efficiency and increasing emissions.

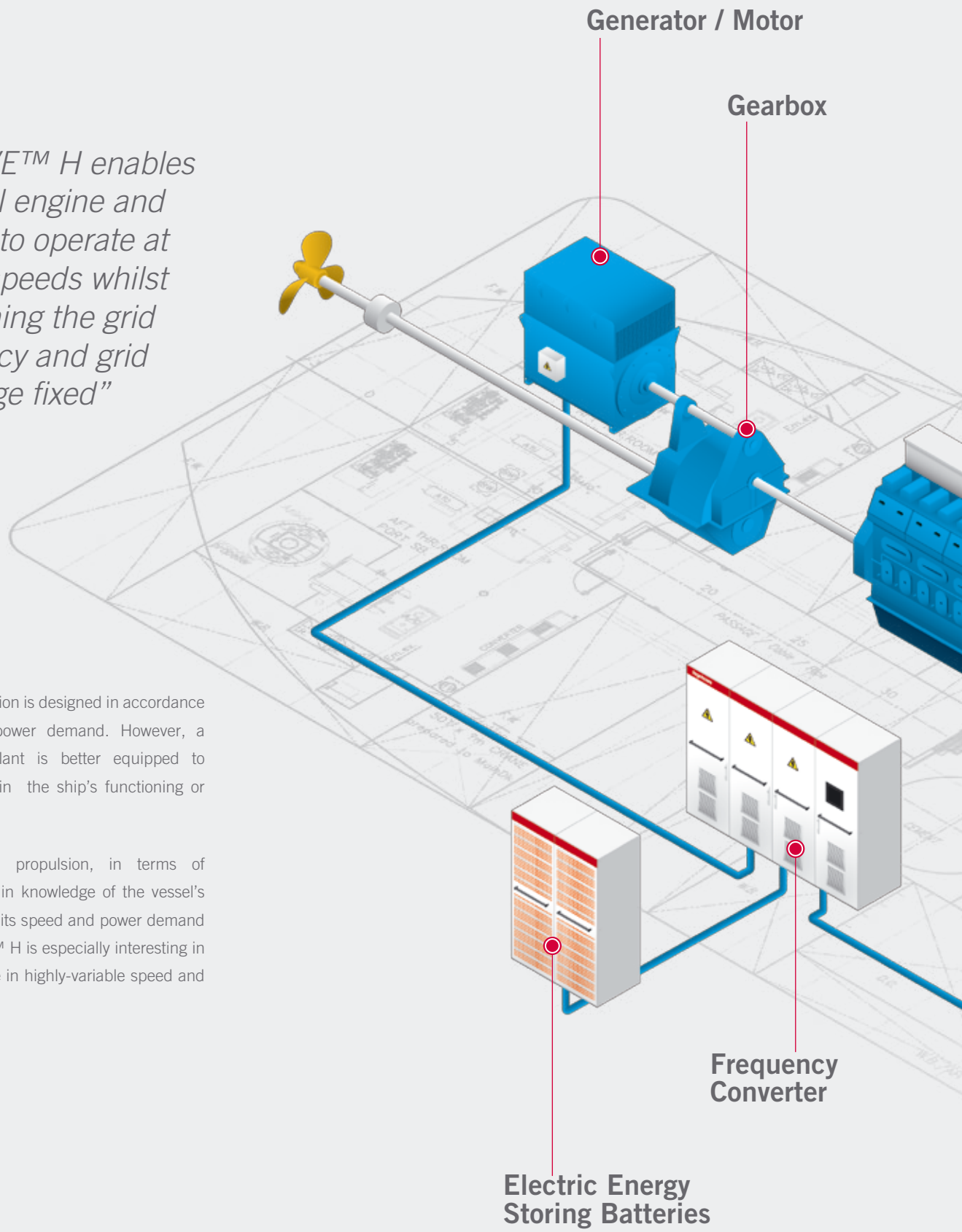
In modern hybrid propulsion systems, the inclusion of power electronics for controlling the shaft generator, using INGEDRIVE™ H, enables the diesel engine and propeller to operate at variable speeds whilst maintaining the grid frequency and grid voltage fixed.

The propulsion power is delivered using a combination of mechanical power (delivered by diesel engines), and/or electric power (through variable speed electric motors). This combination leads to an extensive operating flexibility, making it possible to precisely provide the power and torque in all of the vessel's operating modes.

"INGEDRIVE™ H enables the diesel engine and propeller to operate at variable speeds whilst maintaining the grid frequency and grid voltage fixed"

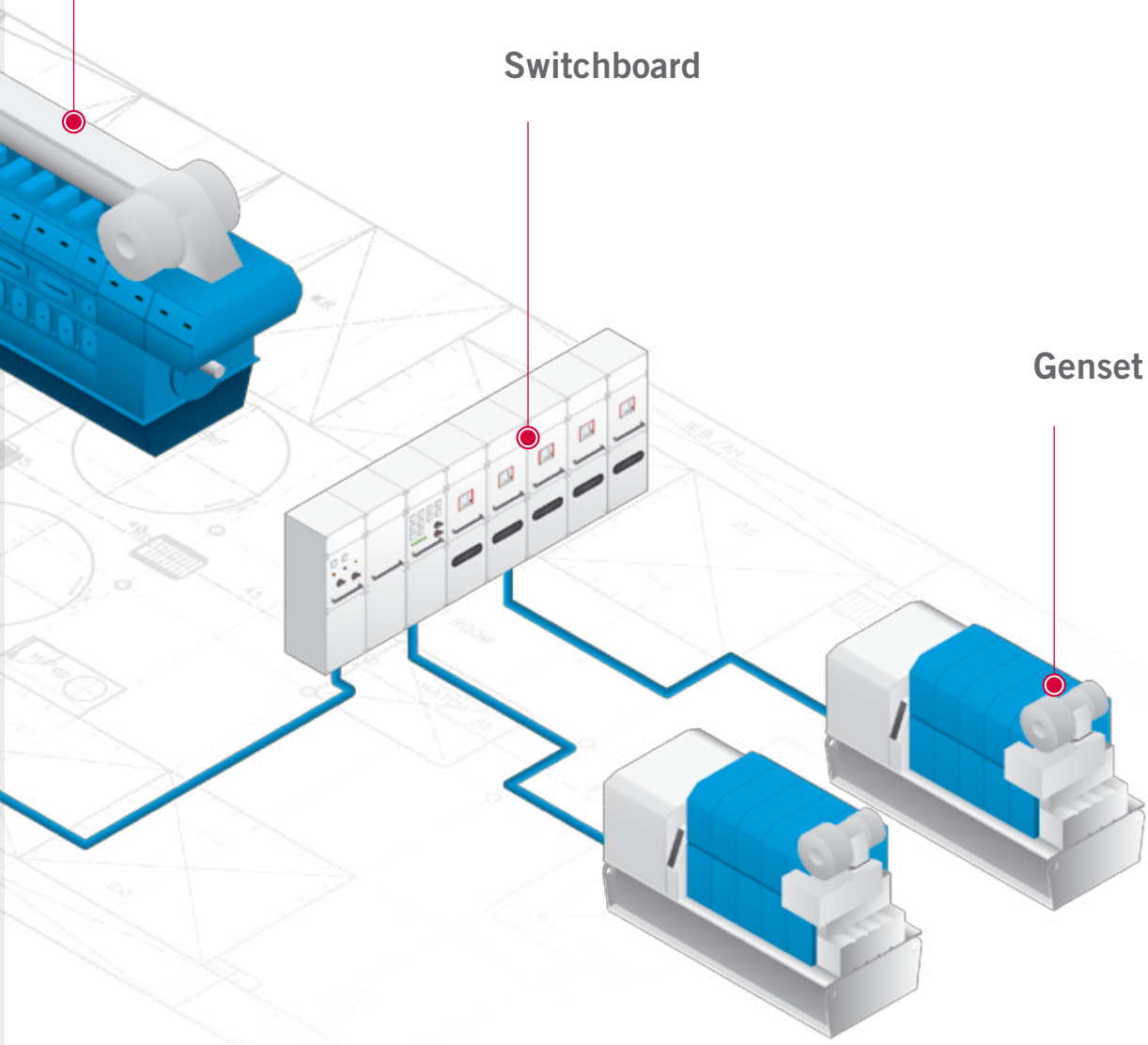
A mechanical propulsion is designed in accordance with its maximum power demand. However, a hybrid propulsion plant is better equipped to respond to changes in the ship's functioning or even its life cycle.

The key to hybrid propulsion, in terms of maximising ROI, lies in knowledge of the vessel's operating modes and its speed and power demand profiles. INGEDRIVE™ H is especially interesting in vessels which operate in highly-variable speed and power modes.



"What drives and propels the world are not machines but ideas instead"

Victor Hugo



Hybrid Energy Storage Systems

The consolidation and maturity of Electrical Energy Storage Systems (EESS) using batteries and ultracapacitors, together with the expectations created by fuel batteries, already make the use of these systems a reality in some types of vessels, such as the ones designed for transporting people and vehicles.

EESSs can be used to try to ensure that diesel gensets reach their minimum specific consumption point at all times (fuel consumption divided between the power delivered to the shaft).

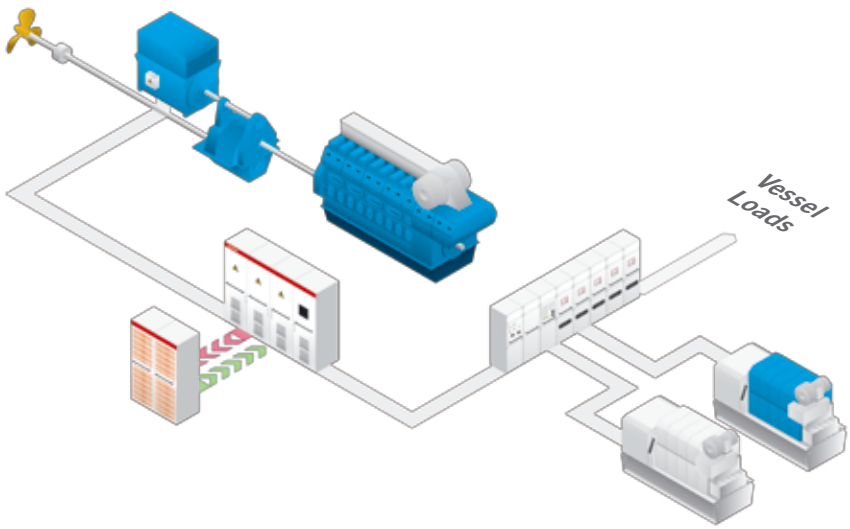
The rotational speed in the gensets in conventional vessels with AC distribution is constant and has a specific value to ensure a constant frequency, equal to 50 or 60Hz. Generally speaking, the operational point with minimum specific consumption corresponds to this speed and a power delivered in the shaft of between 75--80% of the maximum power.

Thus, when the power demand is less than the power corresponding to the minimum specific consumption point, the genset supplies more power than necessary and this is stored in the EESS. However, when demand is great, the EESS will supply power/energy and there the power delivered by the genset is less.

"Energy storage systems allow diesel gensets to reach a minimum specific consumption point"

In order for the vessel to have this functionality, EESSs with a medium-high power and energy storage capacity are required.

EESSs can also be used to avoid high acceleration and deceleration gradients in gensets over short intervals of time, which involve an increase in fuel consumption, emissions, noise, vibrations, etc. Thus, power demands with peaks or high, quick gradients, due to fast acceleration/deceleration processes for example or dynamic positioning with strong disturbances, could be borne by EESSs. This functionality requires EESSs with medium-high power and medium-low capacity.



INGEDRIVE H

"INGEDRIVE™ H guarantees the maximisation of vessel efficiency"

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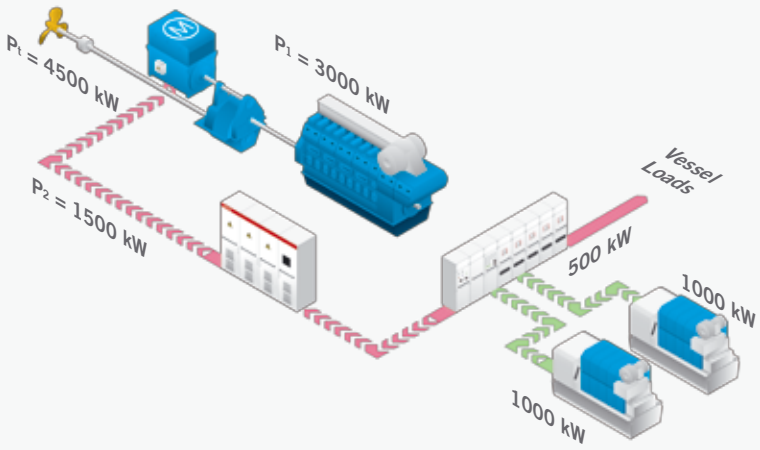
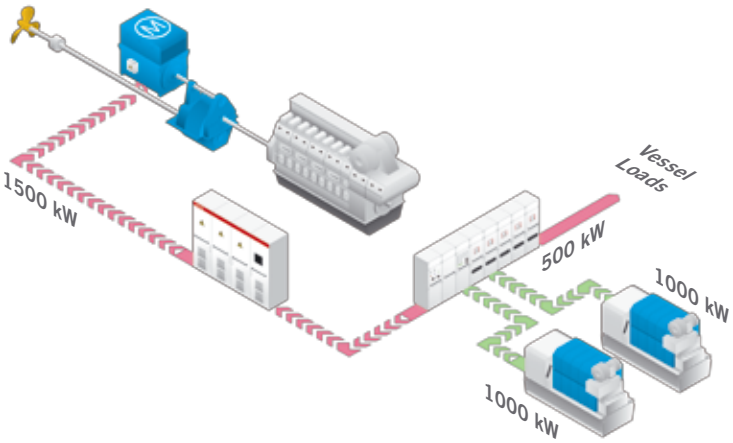
Operating Modes

PTI - Booster Mode

Mode selected for maximum speed. The shaft generator functions as an auxiliary motor (P_2), and works concurrently to the main diesel engine (P_1). Hence, the main propeller receives a power of $P_{total} = P_1+P_2$.

The gensets supply electrical power for both the propulsion (P_2) and for the ship's consumers.





PTI - Diesel - Electric Mode

This mode is used at low speeds and does not need the main diesel engine, reducing the need for maintenance.

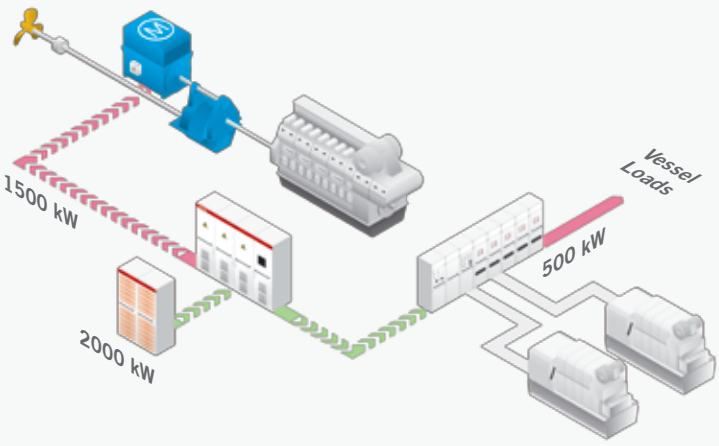
The gensets are functioning and feed the ship's loads as well as the main propulsion. The shaft generator functions in this case as a motor via the INGEDRIVE™ H.

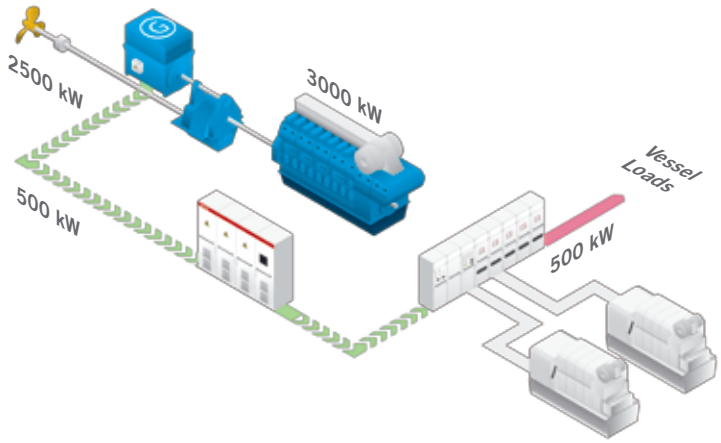
It is a mode that can also start operating in the event of a failure in the main diesel engine ("Power Take Home", PTH functionality) and which makes it possible for the vessel to return home safely to be repaired.

PTI - Fully Electric Mode

In this mode, the batteries generate the energy needed for both the propulsion and for the vessel's consumers. The main diesel engine and the gensets are off, eliminating gas and noise emissions.

It obviously also permits the "Power Take Home" PTH functionality.





PTO - Transit Mode

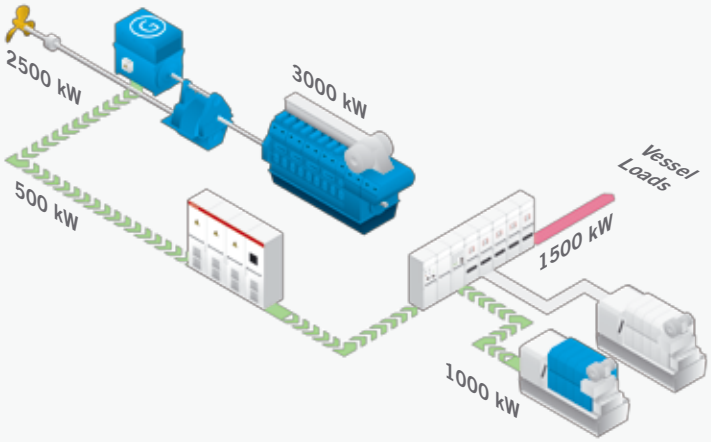
The main diesel engine supplies the power needed for the propulsion as well as for the ship's consumers. Therefore, the gensets are off.

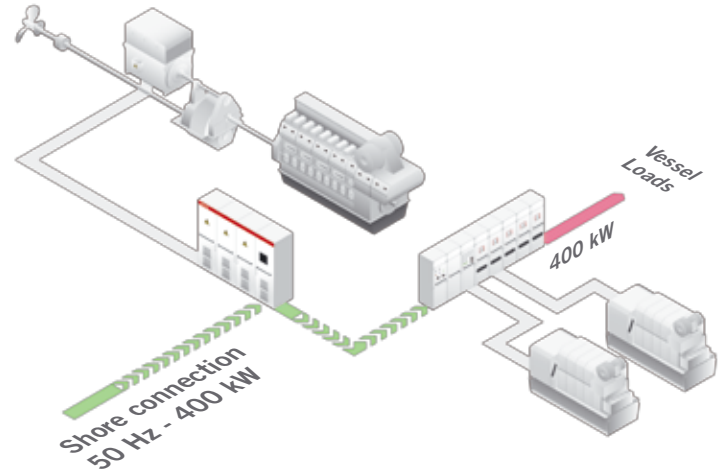
The diesel engine functions at variable speed, and INGEDRIVE™ H in PTO mode supplies the ship's electrical requirements.

This mode provides a significant reduction in the consumption of fuel and emissions during sailing.

PTO - Parallel Mode

This mode is used in cases in which the power required for the propulsion and for the vessel loads is higher than the gensets can provide by themselves. In these cases, the main diesel engine works at partial load and variable speed to optimise the efficiency of the propeller and one of the gensets also starts working.





PTO - Shore Connection Mode

This mode is used when the vessel is in port and is connected to the existing port power supply. In Shore Connection Mode, INGEDRIVE™ H enables the connection to any port regardless of whether its grid is 50 or 60Hz.

In this mode, all engines (the main one or the gensets) can be switched off, with the subsequent reductions in emissions and fuel savings. Noise and vibrational levels are also reduced to a minimum.

"INGEDRIVE™ H solutions are especially relevant to vessels that operate over a wide speed range"

INGEDRIVE LV400 Water cooled

INGEDRIVE™ H solution Advantages

Reduced consumption

Emissions and fuel consumption are reduced, due to the fact that when the operating modes are optimised, the diesel engine's speed is reduced.

Flexibility

Furthermore, switching between the different operating modes is quick and easy, thus making the **system highly-flexible**.

Cost reduction

Given that the number of operating hours is reduced in the gensets and propellers, their **life cycle increases**. Likewise, the **maintenance** intervals are longer. Hence associated costs are **reduced**.

Power increase

Using INGEDRIVE™ H, the electrical machine can work as a generator or as a motor. When it works as a motor, it can work alone or together with the main diesel engine. Therefore, the **propulsion options increase**.

Redundancy and high reliability

Likewise, the fact that the main propeller can be driven by the diesel engine and the electrical motor, makes the **propulsion system redundant and highly reliable**.

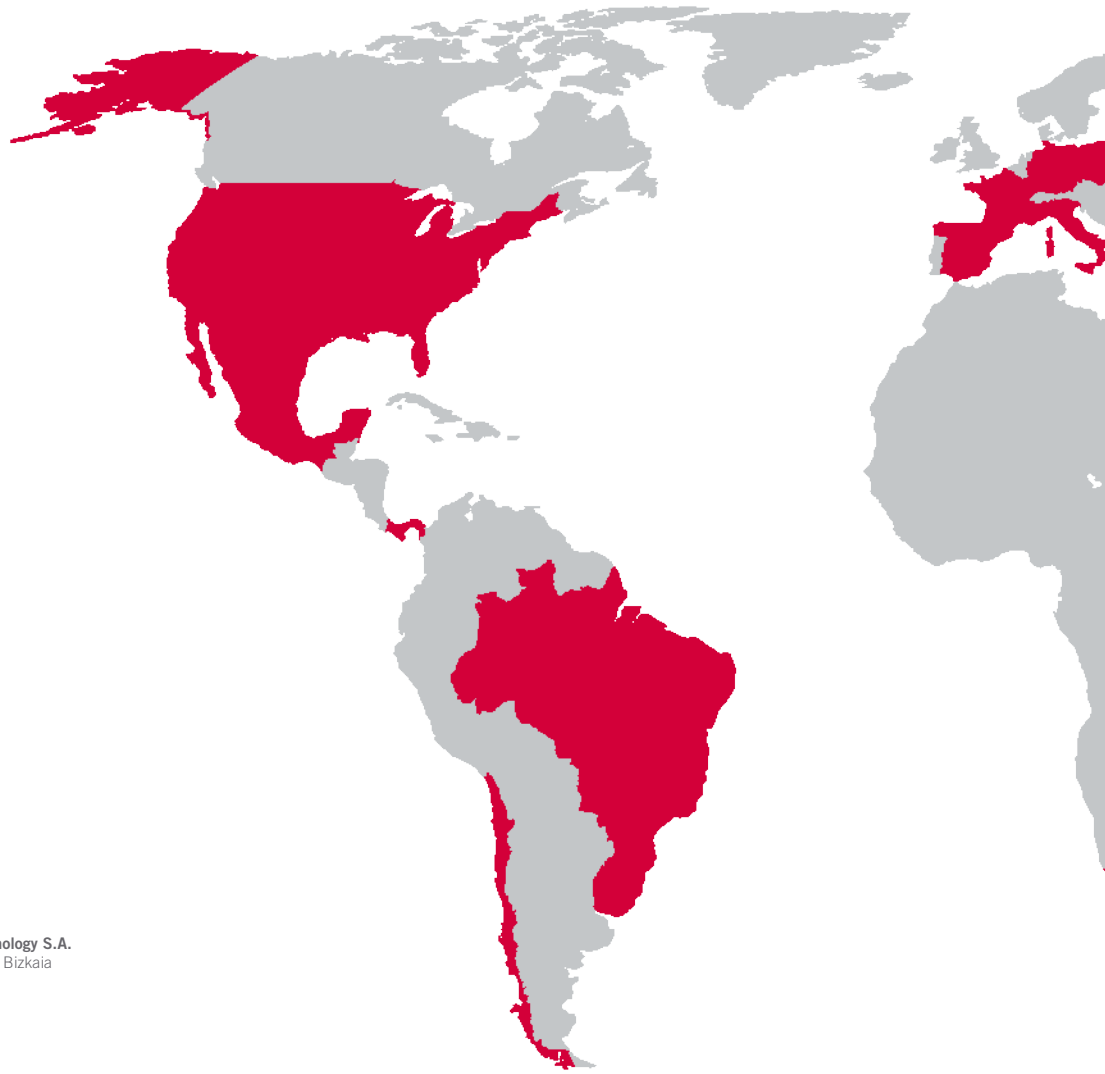
Safety

The system's **safety is increased** thanks to the Power Take Home (PTH) functionality.

Noise and vibration reduction

Acoustic noise and vibrational levels are significantly reduced, thus increasing comfort on board the vessel.

Worldwide Presence



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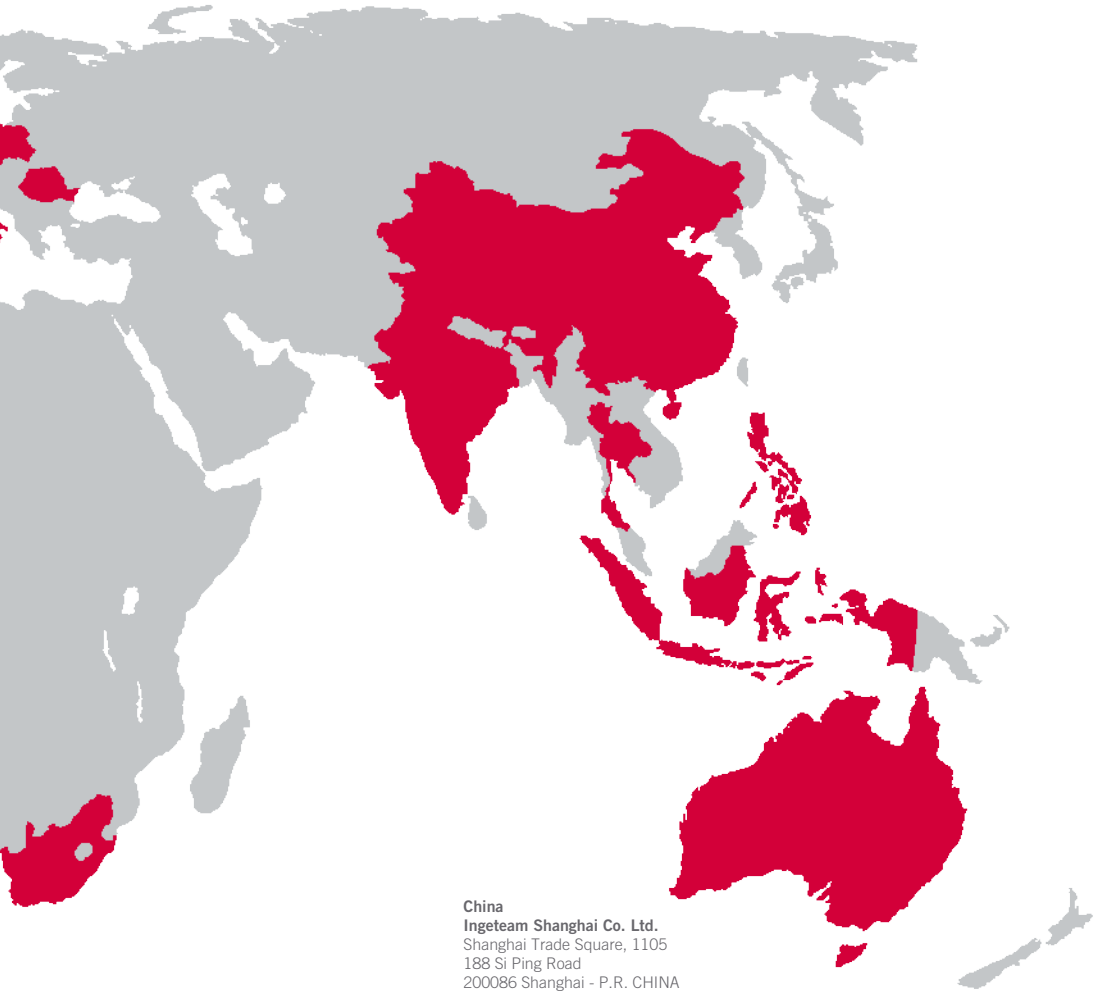

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