INGEDRIVE™

INGEDRIVE™ E3-Ship

Highly-Efficient & Compact Integrated Power System for Electrically propelled vessels

Ingeteam

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.

INGEDRIVE™ E3-Ship

Highly-Efficient & Compact Integrated Power System for Electrically propelled vessels

Electric-Hybrid Propulsion in Ships

In a market as competitive as marine transport, operational costs of vessels, in which fuel consumption plays an essential role, must be reduced.

Climate change policies are creating significant restrictions in terms of emissions in the sector, resulting in protected areas declared as Emission Control Areas (ECAs) in which vessels must sail emitting an extremely low and controlled content of polluting gases and even non-existent in some cases.

Ingeteam's strong commitment to the environment and to improving energy efficiency enables us to work actively on developing new technological solutions related to electrical plants and propulsion for the new generation of hybrid-electric vessels with a significant reduction in fuel and emissions.

In new-generation vessels, hybridisation can take several forms: at propulsion level, by combining mechanical and electrical propulsion in the powertrain; at energy source level, by combining the sources based in internal combustion machines (diesel or gas) with energy storage systems (batteries, ultra-capacitors, fuel cells, etc.) and even with other energy sources categorised as renewable (photovoltaic, mini wind power, etc.). In sophisticated systems, hybridisation can be present both in the powertrain and in the power generation path or power sources.

INGEDRIVE™ E3-Ship permits the integration and optimal functioning of all of the electrical power generation systems, energy storage systems and loads in vessels with electrical propulsion.

With the INGEDRIVE™ E3-Ship solution, gensets can operate independently and at variable speed, always finding the optimum operating point in terms of fuel consumption and emissions in any load mode.

The INGEDRIVE™ E3-Ship system contains the following types of subsystems or power electronics interfaces:

- Generation side power electronics interface subsystem
- Distribution subsystem
- Propulsion side power electronics interface subsystem
- Ship-services load side power electronics interface subsystem
- Energy storage side power electronics interface subsystem

Fuel consumption, emissions reduction, as well as volume, weight and the cost of the solution are highly benefited by using INGEDRIVE™ E3-Ship, maintaining and even improving reliability, functionality, safety and maintenance requirements.

"By using the INGEDRIVE E3-Ship system, fuel savings can reach up to 24% in offshore vessels depending on the operating mode compared to conventional systems with generation at constant speed"

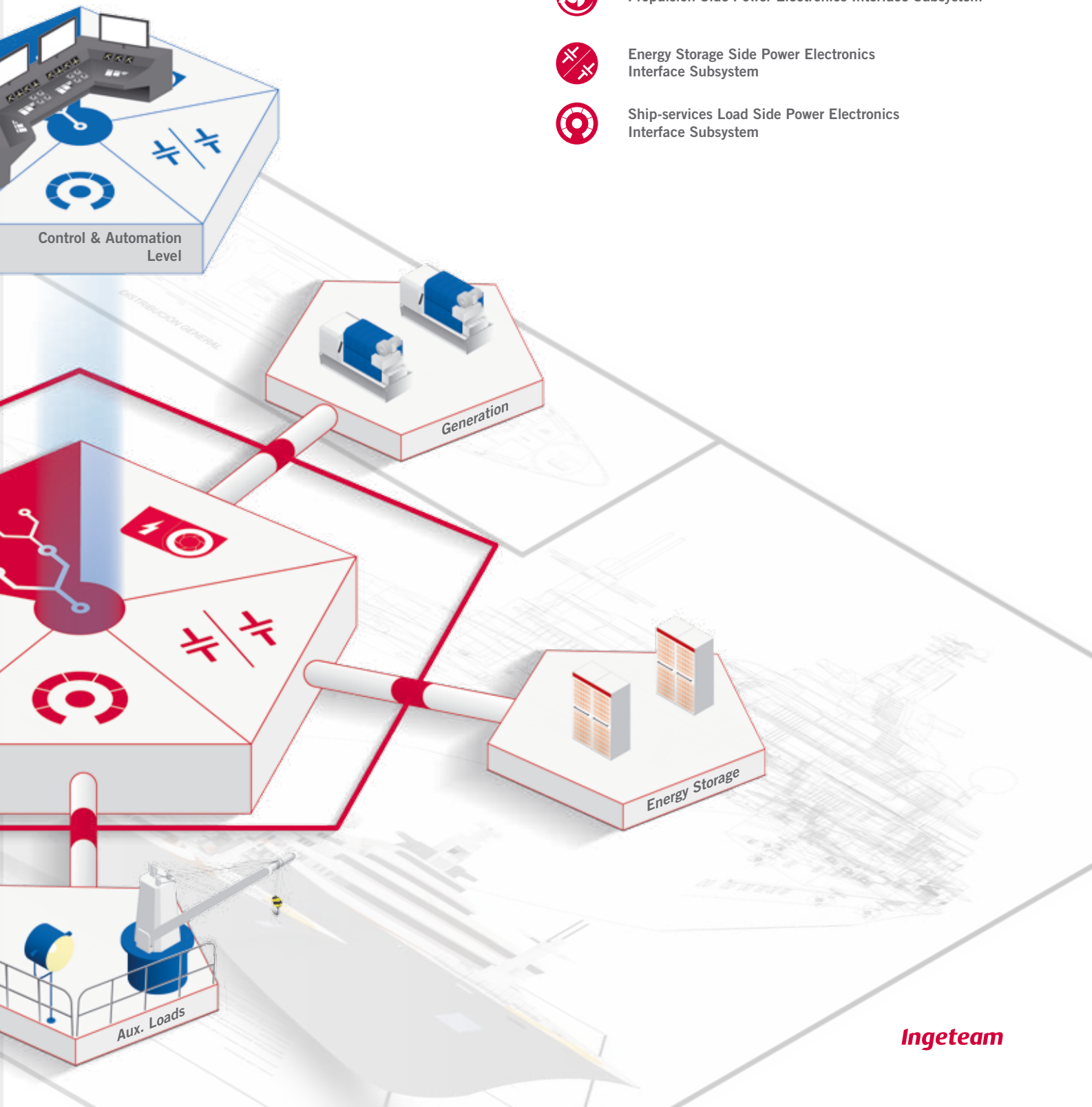
Generation Side Power Electronics Interface Subsystem

Distribution Subsystem

Propulsion Side Power Electronics Interface Subsystem

Energy Storage Side Power Electronics Interface Subsystem

Ship-services Load Side Power Electronics Interface Subsystem



Ingeteam

Generation Side Power Electronics Interface Subsystem

The generation side power electronics interface in INGEDRIVE™ E3-Ship is preferably based on highly energy-efficient Active Front End (AFE) rectifier converters. By connecting them to different generators, a highly-efficient and robust DC distribution system is achieved, with highly-precise voltage control and rapid dynamic responses and high-quality signals in voltages and currents both on the DC and AC side.

The generators, which can be both synchronous (with separate excitation or permanent magnets) and asynchronous, operate with a power factor very close to the unit.

The voltage in the DC distribution system is controlled very precisely with a rapid dynamic response, allowing generators to operate in a wide range of speeds. The high performance obtained in terms of control and dynamics enables the activation of active damping strategies for improving stability, power signal quality and, the general robustness and reliability of the distribution system.

The INGEDRIVE E3-Ship solution allows several generation side power electronics interface subsystems and/or AFEs in the same subsystem to work in parallel, regulating the bus voltage while controlling the load sharing between power sources. To achieve this, there are two options or operating modes in terms of control:

1. Master-slave control mode with ultra-fast, secure communication between AFEs, in which there is a master which regulates the bus voltage and imposes the power set points on the others.
2. Autonomous mode without the need for communication between different AFEs, where all of the AFEs operate in master mode, regulating the bus voltage but with an extra ‘droop’ control loop which guarantees a controlled power sharing.

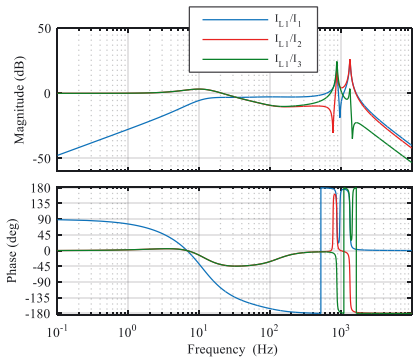
"INGEDRIVE™ E3-Ship allows the operation of the gensets at variable speed with no need for electrical synchronization between them, thus enabling the optimization of the fuel consumption and emissions"

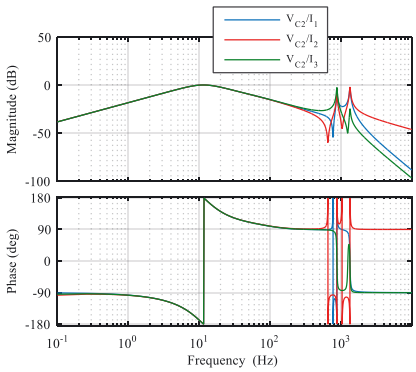
Distribution Subsystem

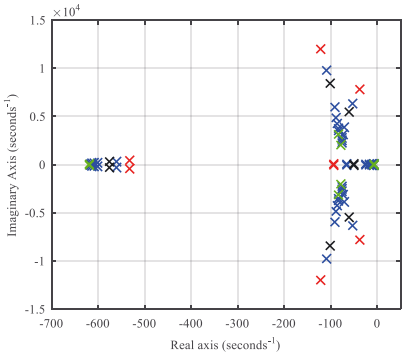
The integration of different power subsystems in the INGEDRIVE™ E3-Ship system is performed using a flexible DC distribution system which can be adapted to any type of electrical and machine room layout in a vessel. The mixture of centralised and distributed topologies makes it possible to maximise the advantages of DC distribution systems without making their installation/deployment in a vessel more expensive and/or difficult.

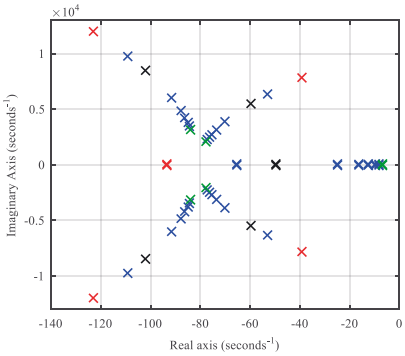
The DC power distribution design capacity in reconfigurable single- or multi-zone topologies in the INGEDRIVE™ E3-Ship solution makes it possible to achieve high levels of safety and redundancy: it is possible for example that different areas such as port side and star board side can be considered as joint or separate using a DC bus-tie.

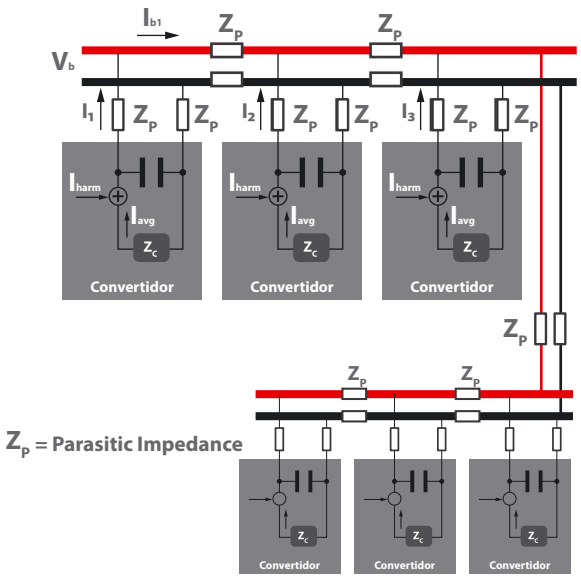
The calculation, sizing and general design of the DC distribution system in the INGEDRIVE™ E3-Ship solution is carried out using advanced analysis and simulation software tools. The design of the distribution system itself (buses & power lines design) together with the design of advanced active damping control strategies, ensure a stable, robust and well damped DC system by design. The high stability margins & high power quality obtained ensures the reliability of the complete system.











[1] DC power quality, DC voltage & current ripple as well as DC voltage & current harmonic content

Propulsion Side Power Electronics Interface Subsystem

The propulsion side power electronics interface in INGEDRIVE™ E3-Ship is based on highly energy-efficient IGBT inverter type converters which, together with the associated control system, permit highly-precise speed and torque control in propulsion motors, with high dynamic responses and high power & signal quality.

The built-in control system allows the torque and speed regulation of different electric motor technologies (asynchronous, synchronous, permanent magnet). The control system also includes "sensorless" control strategies.

The subsystem includes different filtering technologies (LC filter, dV/dt filter, common mode filter, EMI filter) in order to minimise distortion and harmonic signal content both at the inlet (DC side) and the outlet (AC motor side), as well as electromagnetic emissions and signals in common mode.

"The converters together with the associated control system permit highly-precise speed and torque control with high dynamic responses and high power & signal quality"

Energy Storage Side Power Electronics Interface Subsystem

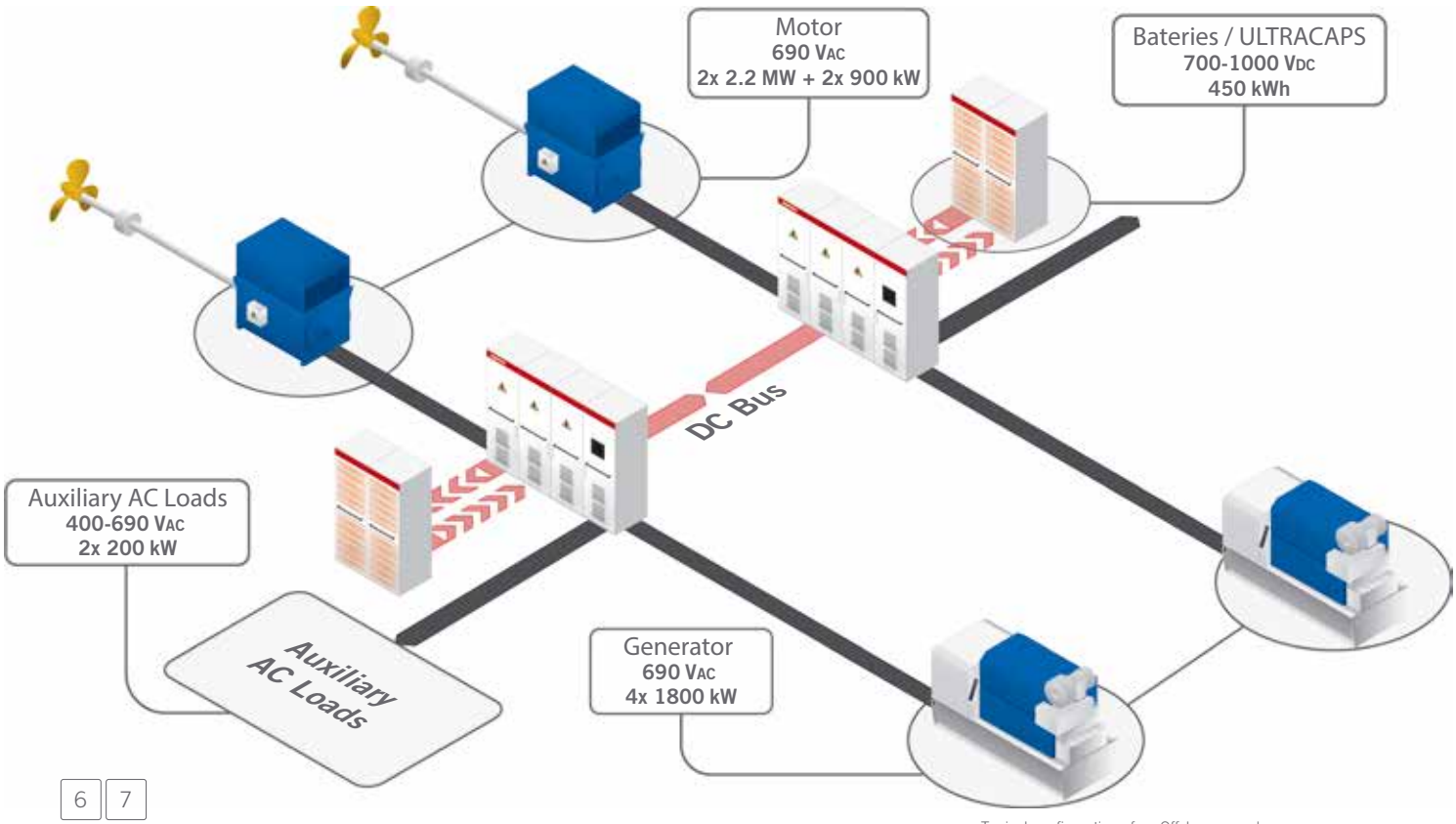
In INGEDRIVE™ E3-Ship solutions, the integration of the energy storage systems (batteries or ultracaps) is performed using highly energy-efficient DC-DC converters, ensuring a constant output voltage for any energy storage system state of charge.

Despite energy losses due to the DC-DC converter, the global system's energy efficiency is better than that obtained when the storage system is directly connected to the distribution grid without the DC-DC converter.

Other aspects such as protection, electrical generator size and cost optimisation, power flow control and energy management, useful life of gensets, amongst others, are improved by using DC-DC converters for integrating energy storage systems in DC distribution grids in which diesel or gas gensets are also included.

The built-in control system permits voltage regulation with peak-shaving functional features for diesel/gas gensets, voltage regulation with the option to participate in a droop control strategy in DC for the load sharing, and power and current regulation for controlling the storage system's recharging process. It also includes advanced functional features for protecting the storage system and integration into the automation system, the BMS (Battery Management System), the PMS (Power Management System) and the EMS (Energy Management System).

The subsystem includes different filters for minimising distortion and harmonic signal content both at the inlet and outlet as well as electromagnetic emissions and signals in common mode. These filters ensure compliance with requirements imposed by the major suppliers of energy storage systems in terms of maximum ripple, harmonic content in DC, EMI levels, and voltage levels in common mode.



Typical configuration of an Offshore vessel

"Energy Storage Systems (EES) enable the gensets to work at high efficiency operating points. Furthermore, ESS allow sailing at low speed and/or harbor maneuvering with zero emissions, depending on the available energy stored on the ESS"

Ship-Services Load Side Power Electronics Interface Subsystem

In the integrated INGEDRIVE™ E3-Ship solution and using the ship-service load side power electronics interface, different AC distribution micro-grid subsystems at constant frequency and voltage are generated which can work in reconfigurable single- or multi-zone topologies. Feeding the vessel's essential and non-essential AC loads is guaranteed (auxiliaries, service load, hotel loads, etc.).

For the generation of constant AC voltage & frequency grids, the INGEDRIVE™ E3-Ship system uses inverters configured as static converters, which can work in parallel without the need for communication between each other. Auxiliary gensets can even participate in these grids, operating in parallel with the static converters without the need for communication. The load sharing of both active and reactive power is proportionally ensured depending on the size of each inverter system and generator operating in parallel to the grid.

The ship-services load side power electronics interface also permits AC connection to the port (onshore connection). The AC micro-grids in the vessel (which in sailing mode work in isolated mode) can be connected in port to the general power distribution grid. Inverters in static converter mode permit bidirectional functioning and so offers the real possibility of controlled power/energy exchange between the vessel and the port's electrical grid in both directions if necessary (shore to ship and ship to shore power transfer).

The ship-services load side power electronics interface subsystem can operate as a controlled recharging system of the electrical on-board energy storage systems (batteries, ultra-capacitors, capacitors). Normally, when in port, the ship takes power from the port's electrical power system to feed the service loads or even to recharge the on-board energy storage systems in a controlled manner (shore to ship power transfer). However, the energy stored in the vessel can be transferred to the port's grid in the event of an emergency, improving stability, etc. (ship to shore power transfer).

Protection System: Basic and Selective Low-Level Protection

In the INGEDRIVE™ E3-Ship built-in solution, each user connected to the DC distribution is protected using DC fuses, both in the positive and negative pole. There is also the possibility of installing a switch to isolate the user in the event of a fuse failure.

DC fuses are calculated and selected to ensure the coordination and selectivity of the protection system. Only blows the fuse connected to the user in short-circuit. The system ensures that a black-out does not occur while the user is being isolated during the fault.

In bi-or multi-zone DC distribution systems, these zones are joined or separated using a controlled bus-tie switch. The bus-tie in the INGEDRIVE™ E3-Ship solution can be electronic (based on power semiconductors) or can be a combination of ultra-rapid fuses and controlled switch disconnectors. In both cases, the rated characteristics of the bus-tie are 1500Vdc and up to 5000 A.

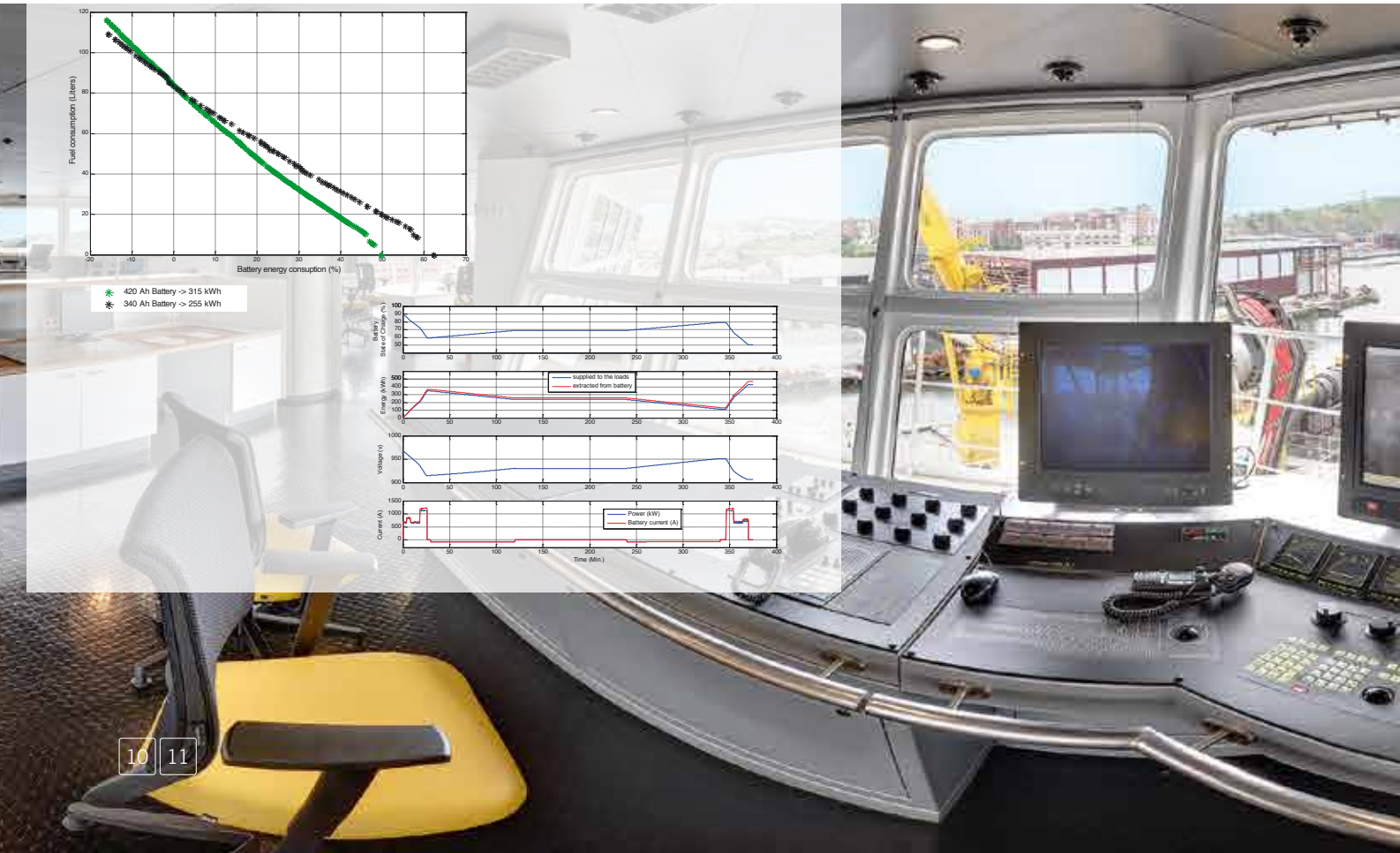
- In the case of a bus-tie using a combination of an ultra-fast fuse and a switch disconnector, in the event of a failure in any of the zones, the bus-tie's ultra-fast fuse is the first to open and isolate the zone.
- In the case of using the electronic bus-tie based on semiconductors, the opening of the bus-tie is very fast (few microseconds) and is always less than the opening time of the fuses in the case of each user.

Integrating the Automation System, PMS and EMS

In the integrated INGEDRIVE™ E3-Ship solution, all of the control units corresponding to all of power electronics converters and subsystems support field communications compliant with the most common industrial communication protocols: Profibus, CAN, CAN open, Modbus TCP, Industrial Ethernet. Hence, the integration and exchange of signals between the converters present in the solution, the automation system, the alarms management system, the PMS, the EMS and the BMS, amongst others, is ensured.

The INGEDRIVE™ E3-Ship solution makes it possible to receive operating limits and set points from both the PMS and EMS to ensure the management of power and energy (available and reserve) in the built-in power system. In turn, the PMS and EMS systems are continuously informed on the status of each subsystem and the INGEDRIVE™ converters, the aim being for both systems to be able to dynamically reconfigure their power and energy management strategy.

As suppliers of the INGEDRIVE™ E3-Ship solution, Ingeteam offers its knowledge and tools to system integrators, to facilitate the development and programming of optimum energy management strategies (EMS). To achieve this, specialist software developed by Ingeteam is available, which includes energy and loss models (with huge scope for parametrisation) of the main power conversion stages in the E3-Ship solution. This tool can be used to therefore make simulations of the complete system and obtain estimates in terms of energy efficiency and fuel consumption, observing the progress of the state of charge of different on-board energy suppliers. Hence, it is possible to assess different energy strategies, with low computational costs, for different power profiles and missions or operational modes in a vessel. The use of this tool allows the system integrator to acquire first-hand knowledge of the complete system in terms of energy, using which they can develop and automate optimum energy policies on board depending on the vessel's mission, its usual power demand profile and its operating modes.



Main Benefits of INGEDRIVE™ E3-Ship

High energy efficiency: Up to 30% savings in fuel depending on the vessel, its application and its operating modes.

Permits the operation of gensets at variable speed, always looking for the operating point with **minimum fuel specific consumption**.

Compact, highly-reliable and safe solution: Design procedure based on recommendations and standards defined by the most important Classification Societies in the sector. Guarantees stability, signal & power quality and system protection by design.

Efficient integration of electrical energy storage systems.

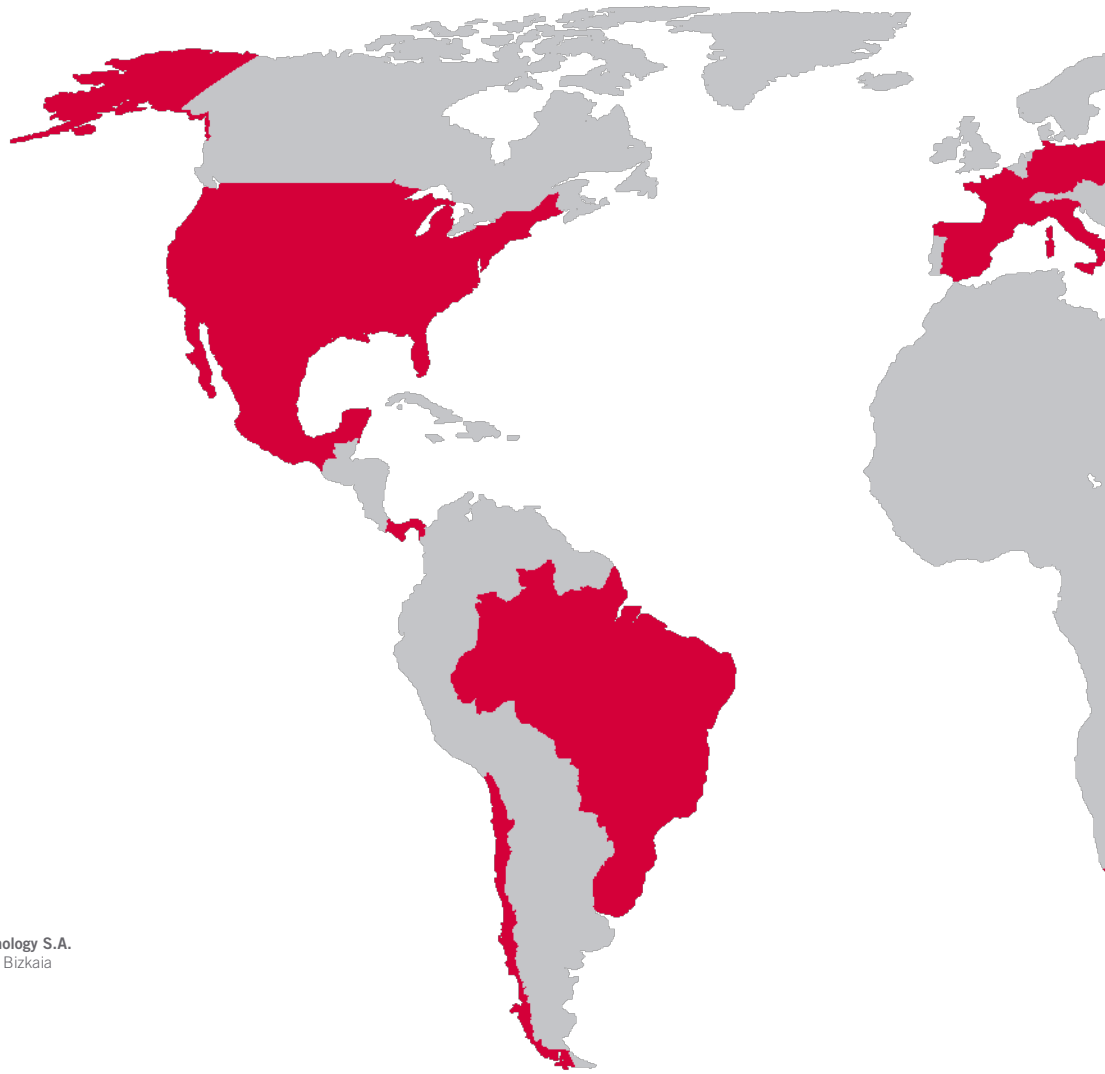
Electrical propulsion with the option to operate at **zero emissions** from batteries.

Vessel power system integration with **ON-SHORE connection**.

Versatile and **highly-dynamic** control, management and reconfiguration of energy and power flows.

INGEDRIVE™ E3-Ship

Highly-Efficient & Compact Integrated Power System for Electrically propelled vessels



España
Ingeteam Power Technology S.A.
Parque Tecnológico de Bizkaia
Edificio 110
48170 Zamudio
Bizkaia - SPAIN
(+34) 944 039 600

Italia
Ingeteam S.r.l
Via Emilia Ponente 232
48014 Castel Bolognese (RA) - ITALIA
(+39) 0546 651490

Francia
Ingeteam SAS
Parc Innopole
BP 87635 - 3 rue Carmin - Le Naurouze B5
F-31676 Toulouse Labège cedex - FRANCE
(+39) 0561 250000

Alemania
Ingeteam GmbH
Herzog-Heinrich Strasse 10
D-80336 - München - DEUTSCHLAND
(+49) 89 99 65 38 0

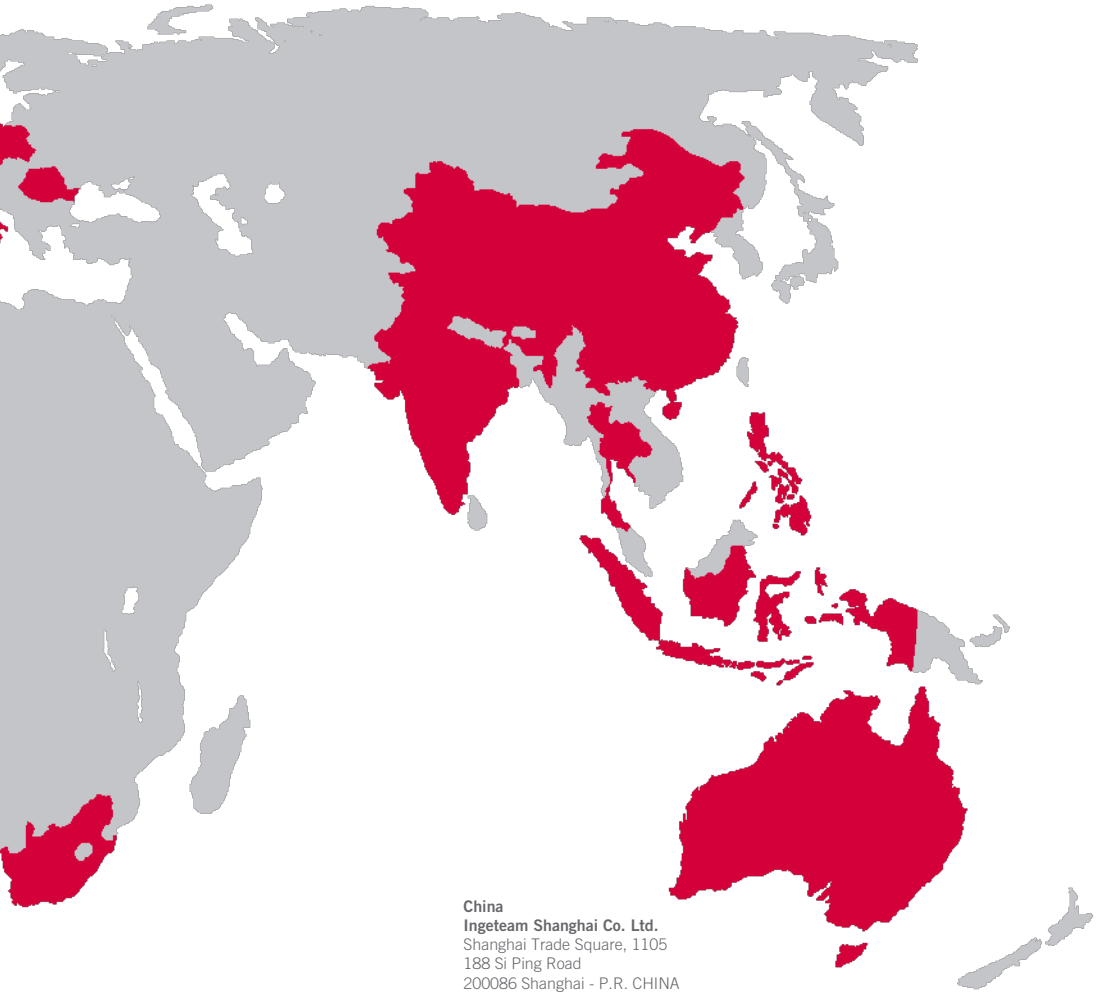
República Checa
Ingeteam a.s.
Technologická 371/1
70800 Ostrava
Pustkovec - ČESKÁ REPUBLIKA
(+420) 59 732 68 00

Polonia
Ingeteam Spzoo
Rzymowkiego 53
02-697 Warsaw - POLONIA
(+48) 22 548 00 01

EEUU
Ingeteam Inc
3550 W. Canal Street
MILWAUKEE, WI 53208 - USA
(+1) 414 934 4100

México
Ingeteam S.A. de C.V.
Ave. Revolución, 643, Local 9
Colonia Jardín Español
Monterrey, N.L. 64820 - MÉXICO
(+52) 81 83 11 48 58m

Panamá
Panamá S.A.
alle Manuel Espinosa Batista, edificio
Torre Internacional Business Center,
Apto./Local 407
Urbanización Bella Vista-Corregimiento
Bella Vista
Distrito de Panamá
Provincia de Panamá



China
Ingeteam Shanghai Co. Ltd.
Shanghai Trade Square, 1105
188 Si Ping Road
200086 Shanghai - P.R. CHINA
(+55) 21 65 07 76 36

Brasil
Ingeteam Ltda.
Rua Luiz Carlos Brunello, 286
Chácara Sao Bento 13278-074
Valinhos SP - BRASIL
(+55) 19 30 37 37 73

Uruguay
Ingeteam Uruguay S.A
World Trade Center,
Torre III, Piso 4
11300 Montevideo - URUGUAY

Chile
Ingeteam SpA
Bandera 883, Piso 211
8340743 Santiago CHILE
(+56) 2 738 01 44

Tailandia
Ingeteam Power Technology S.A.
100/67 Vongcanij bldf. B, 22nd dloor Rama IX
Rd Haykwang
(+66) 224 61798

Filipinas
Ingeteam Philippines Inc.
Unit 330, Milelong Building,
Amorsolo street corner Rufino
Makati City - PHILIPPINES
(+63) 02 3176677

India
Ingeteam Power Technology India Pvt. Ltd.
2nd Floor, 431, Udyog Vihar, Phase III
GURGAON - 122016
Haryana - INDIA
(+91) 124-426-4360

Australia
Ingeteam Australia (Pty) Ltd
Suite 112, Level 1, Mike Codd
Building 232
Innovation Campus, Squires Way
North Wollongong
NSW 2500 - AUSTRALIA

Sudáfrica
Ingeteam (Pty) Ltd
Unit no2 Alphen Park,
Aouth Randjiespark
1682 Midrand - SOUTH AFRICA
(+27) 79 610 9952

ingedrive.info@ingeteam.com

Ingeteam

Ingeteam

www.ingeteam.com

ingedrive.info@ingeteam.com

PC07IPTT01_ / 2017