



GE VERNOVA



**SOLUTIONS FOR
WORLD NAVIES**



GE Vernova's Power Conversion business is trusted by the world's leading navies and coast guards to energize their missions. From full naval-specification, high voltage electric grids for power and propulsion to cost-effective hybrid electrification options.

A NEW NAVAL ERA IS EMERGING, FAST

Fleets need to be mission-configurable, highly capable for military advantage, adaptable for technology insertion, and affordable.

The critical enabler is energy. It unlocks military effects, speed, responsiveness, endurance and connectivity. Through electrification and smarter automation and control, energy in the **Ship's Electric Grid** is scalable and flexible, ready to supply high-energy defense systems and integrate cleaner, more **efficient energy** technologies.

Electrification: Technology to enable the mission

MISSION CAPABILITY

Meet growing power needs

Balance energy supply and demand
Enable propulsion, high-power sensors, ship service loads, and energy weapons

LIFECYCLE CAPABILITY

High reliability and availability

Mature, dependable technology
Reduce opex and through-life costs
Improve energy efficiency and emissions

Military effect is **delivered by the system**, not the components.

Our naval center of excellence teams bring a deep understanding of naval standards, vessel and lifecycle demands.

The emphasis is in providing a scalable system that meets your navy's mission needs.

APPLICATIONS



Aircraft Carriers

GE Vernova provides the complete high voltage Ship's Electric Grid, with the latest QE class ship references producing, distributing and managing over 100 MW electricity to supply integrated, full electric power and propulsion (IFEP) right across the operating base. Shock-rated and highly flexible design layouts.



Destroyers & Frigates

GE Vernova is trusted to energize the world's latest destroyer and frigate programs with reliable power and propulsion. Solutions range from integrated full electric to compact hybrid-electric, providing options for the largest, energy-intensive ships for ASW to lighter frigates. The Ship's Electric Grid is the choice of navies wanting to future-proof scalable electric power for next generation, high-energy combat systems.



Corvettes & Patrol

We combine extensive commercial electric drive ship experience with deep domain naval and coast guard experience to provide cost-effective electrification solutions for light combat and offshore patrol ships. Electric and hybrid power systems are perfect choices for modern, multi-role ships seeing increased mission system power demand but needing sustainable, energy-efficient performance for patrol duties.



Amphibious Ships

Our full integrated- and hybrid-electric power and propulsion systems provide the energy and maneuverability required to manage navies' renewed focus on amphibious fleets' expeditionary missions, advanced command and control and combat systems, and provide excellent fuel efficiency in electric mode at slow speed loitering.



Logistics & Auxiliary Vessels

The latest generation of support ships designed to replenish and refuel fast combat fleets benefits from integrated electric and hybrid ship solutions to provide energy efficiency required for the broad range of speed and operational RAS duties. Advanced automation and control systems include dynamic positioning for vessel tracking and precise position-holding.



Submarines

Solutions and support services for SSK boat requirements, including specialist, low-noise motors and power electronics for power and propulsion, energy storage and management. Integrated system test capability.



Special Platforms

Specialist support and operational vessels are an important part of navies' and coast guards' total capability, from research and survey vessels to rescue ships and icebreakers. Whether the needs are lower carbon options and energy-efficiency for extended missions or low acoustic signatures, power for mission systems or enhanced maneuverability, GE Vernova has proven, cost-effective electric ship and energy management systems in both commercial and naval sectors.

TRUSTED BY THE WORLD'S LEADING NAVIES



**OVER
130
REFERENCES**

GE Vernova has the most electric and hybrid ship system references, leading in applications from the largest, complex warships to the latest support and patrol ships. We bring specialist naval engineering with a commercial mindset, unlocking the benefits of electrification right across the fleet.

The Advance of Naval Electric Propulsion Capability



Type 23, Frigate
Propulsion Power

3MW
(2 × 1.5MW)
1990



Albion Class, LPD
Propulsion Power

12MW
(2 × 6MW)
2000



Type 45, Destroyer
Propulsion Power

40MW
(2 × 20MW)
2010



QE Class, Aircraft Carrier
Propulsion Power

80MW
(4 × 20MW)
2018

Configurable in integrated full electric or hybrid-electric architectures, our dependable naval technologies are shock rated if required, and proven on naval applications from **3MW to 110MW**.

Integrated Full Electric (IFEP)

Vessel Programme	Total	Vessel Sub-Type	Shaftline Type	System Voltage	Drive Technology	Drive Features	Motor Technology	Propulsion Power/Vessel
QEC Aircraft Carrier – RN	2	Aircraft Carrier	Motor	11,000	VDM 25000	PTI	Advanced Induction	80
Type 45 Destroyer – RN	6	Destroyer	Direct Drive	4160	Transformerless	Transformerless PTI	Advanced Induction	40
DDG1000 Destroyer – USN	3	Destroyer	Tandem	4160	Transformerless	Transformerless PTI	Advanced Induction	72
Albion Class LPD– RN	2	Landing Platform Dock	Direct Drive	6600	LCI	PTI	Synchronous	12
Joint Support Ship (JSS) - RNLN	1	Landing Platform Dock	Direct Drive	6600	DFE MV7000	PTI	Induction	18
Mistral Class LHD – MN	3	Landing Helicopter Dock	Azimuthing Pod	6600	LCI	PTI	Synchronous	14
Egyptian LHD - ENF	2	Landing Helicopter Dock	Azimuthing Pod	6600	LCI	PTI	Synchronous	14
ESB/MLP - USN	7	Mobile Landing Platform	Direct Drive	6600	LCI	PTI	Synchronous	20
T-AKE Dry Cargo Support – USN	14	Dry Cargo Support	Tandem	6600	LCI	PTI	Synchronous	22
Rescue Vessel ROCN	1	Submarine Support Vessel	Geared Drive	690	Transformerless	Transformerless PTI	Induction	8
Combat Support Ship (CSS) - RNLN	1	Oiler	Direct Drive	6600	DFE MV7000	PTI	Induction	18
Wave Class AO – RFA	2	Oiler	Tandem	6600	LCI	PTI	Synchronous	14

Hybrid Electric

Vessel Programme	Total	Vessel Sub-Type	Shaftline Type	System Voltage	Drive Technology	Drive Features	Motor Technology	Propulsion Power/Vessel
T23 Frigate – RN	13	Frigate	Hybrid	600	DC	Transformerless PTI	DC	3
T23 Frigate – AdC	3	Frigate	Hybrid	600	DC	Transformerless PTI	DC	3
T26 Frigate – RN	8	Frigate	Hybrid	690	Transformerless	Transformerless PTI	Advanced Induction	7
Multipurpose Offshore Patrol Ship Thacon di Revel Class - MM	7	Frigate	Geared Hybrid	690	Transformerless	Transformerless PTI/PTO	HS Induction	3
Landing Helicopter Dock (LHD) - MM	1	Landing Helicopter Dock	Geared Hybrid	6000	AFE SeaPulse	PTI/PTO	HS Induction	4.5
LHD-8/LHA-6,7,8 – USN	4	Landing Helicopter Dock	Geared Hybrid	4160	DFE SeaPulse	PTI	Induction	7.5
Tide Class LSV – RFA	4	Oiler	Geared Hybrid	690	Transformerless	Transformerless PTI/PTO	HS Induction	5
Norwegian LSV – NDLO	1	Oiler	Geared Hybrid	690	Transformerless	Transformerless PTI/PTO	HS Induction	5
Vulcano Class - MM	1	Oiler	Geared Hybrid	690	AFE SeaPulse	PTI/PTO	HS Induction	3

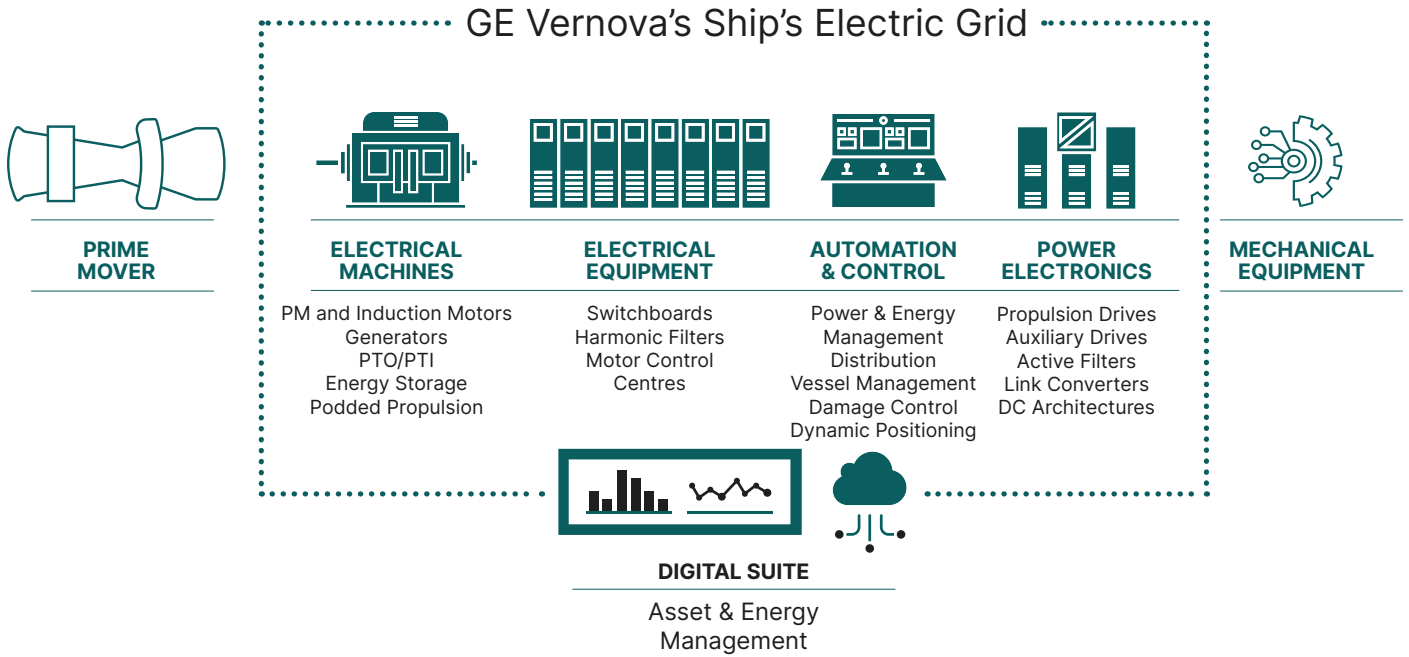
Specialist Electric Vessels

Vessel Programme	Total	Vessel Sub-Type	Shaftline Type	System Voltage	Drive Technology	Drive Features	Motor Technology	Propulsion Power/Vessel
AGXII – RoKN	1	Research Vessel	Direct Drive	690	AFE SeaPulse	Transformerless PTI	Advanced Induction	4
Pourquoi Pas? - MN	1	Research Vessel	Direct Drive	690	DFE MV7000	PTI	Induction	3
Agulhas II - RSA	1	Research Vessel	Direct Drive	3300	AFE MV7000	Transformerless PTI	Induction	9
Polar Research Vessel - Peru	1	Research Vessel	Direct Drive	690	AFE SeaPulse	Transformerless PTI	Induction	7
AOPS – RCN	6	Icebreaker	Direct Drive		DFE MV7000	PTI	Induction	9
Healy - USCG	1	Icebreaker	Direct Drive	6600	Cycloconverter	PTI	Synchronous	22
Antártica 1 Polar Class - Chilean Navy	1	Research Vessel	Direct Drive	690	AFE SeaPulse	Transformerless PTI	Induction	9
ADD – RoKN	1	Submarine Support Vessel	Direct Drive	690	AFE SeaPulse	Transformerless PTI	Advanced Induction	3

NAVAL ELECTRIC POWER & PROPULSION

GE Vernova's Power Conversion business has an industry-leading, complete range of naval electric ship technologies, and decades of experience.

Powerful systems can support energy demands, from propulsion to high-power sensors, service loads and pulse power for defense systems.



Ship's Electric Grid

GE Vernova's Ship's Electric Grid is scalable and flexible—the safe way to generate, distribute and manage power, where and when it's needed around the ship. The grid's benefits are fully and best deployed in an integrated full electric configuration.

Its strength is also in facilitating 'plug-in' of different energy sources, like batteries, future technology insertion, and options to connect mission system modules.

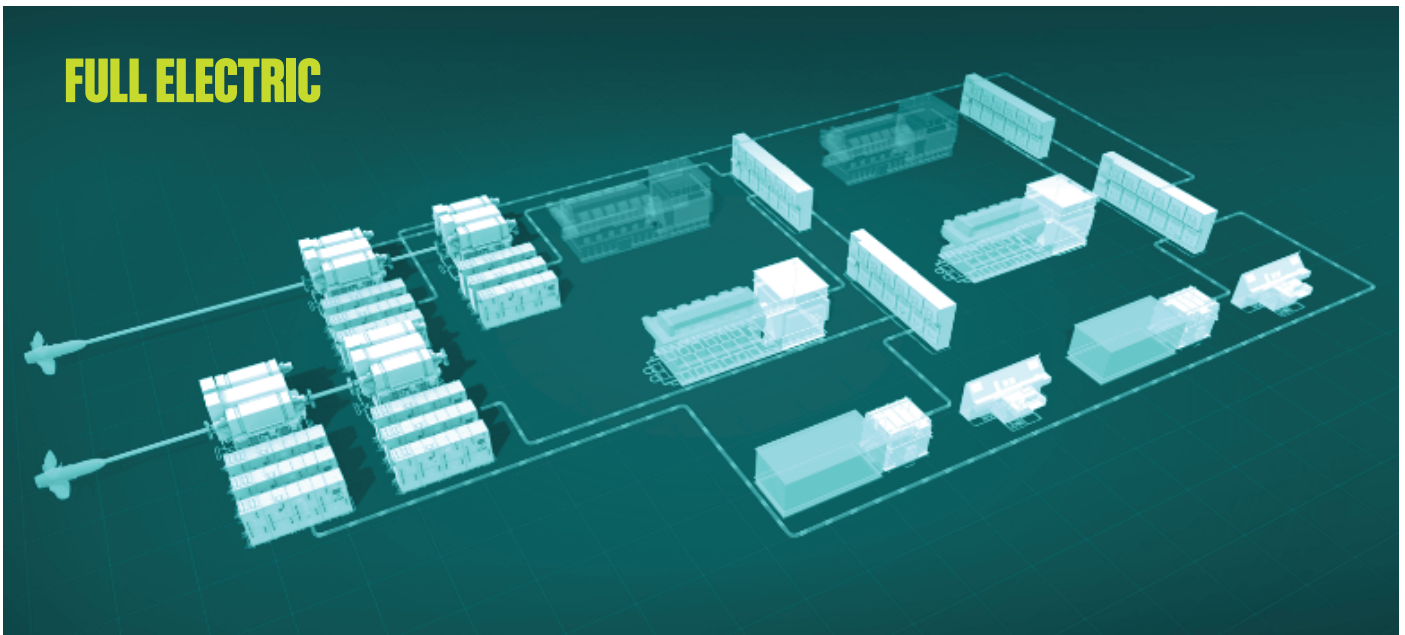
Electrification technologies include naval electric motors and generators, switchboards, and power converters.

Alongside power equipment, the Ship's Electric Grid incorporates the brains of the system—advanced automation, control and power management systems which are also enabling the shift towards more-autonomous and smart operations.

ELECTRIC SHIP CONFIGURATIONS

Integrated full electric power and propulsion (IFEP) solutions provide the greatest flexibility in vessel layout, power scalability and maintainability. Without having a fixed mechanical drive shaft through the ship, powerful propulsion motors and generators can be optimally located in the vessel to help maximize available space, and separation for improved survivability.

Excellent efficiency and availability is achieved through the ability to share all power sources across all power consumers. This enables superb flexibility and responsiveness for different operating scenarios.



Electric drive solutions are just as suited to smaller, more commercial-spec ships in naval and coast guard fleets as to the biggest, higher voltage combat ships. Both can combine power for propulsion and on-board equipment in one system.

AC Architectures

- Standardized but highly flexible, open and configurable.
- Secure, easy to protect and interface AC electrical machines and shore power connections in the Ship's Electric Grid.
- Suitable for both low voltage (LV) and medium-high voltage networks on the vessel. Ideal for integration of transformers.

Advanced AC, enhanced by the latest power electronics

- Can incorporate variable speed generation with link converters, and energy storage with simple DC links.
- Active filtering reduces harmonics and fault limiting can reduce fault current.
- Highly resilient power network

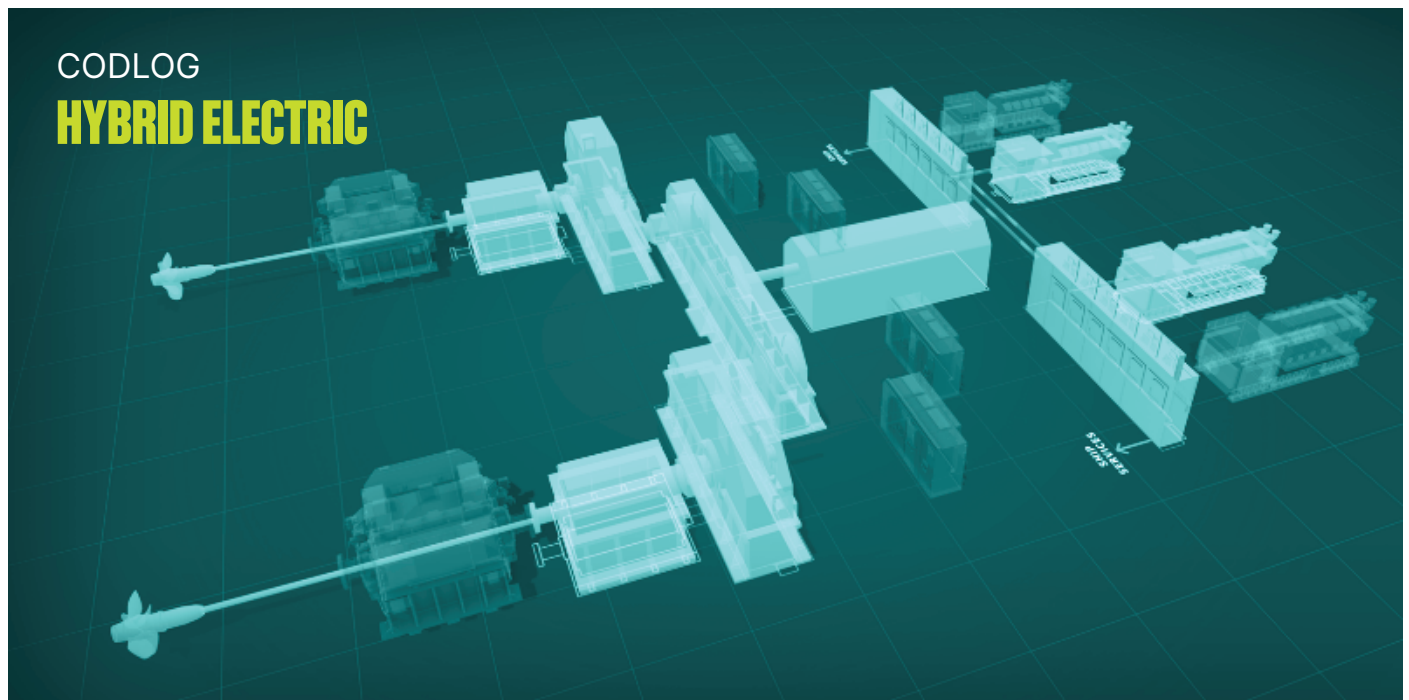
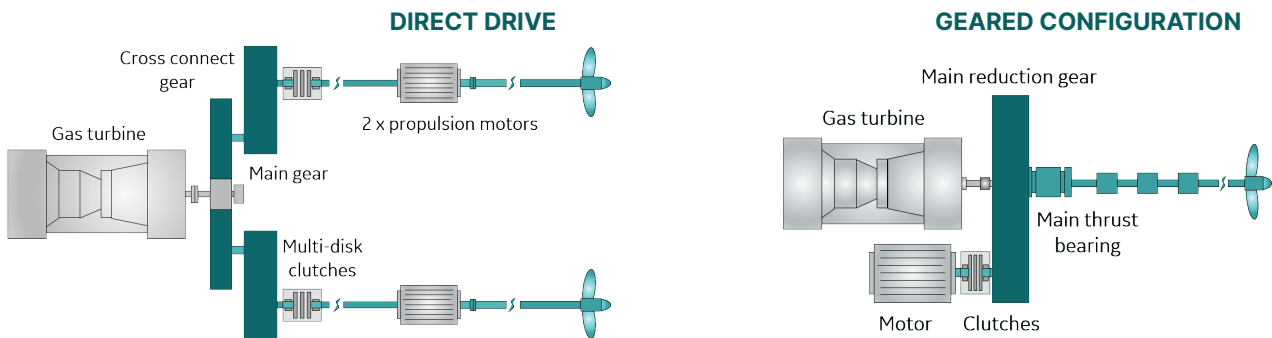
DC Architecture

- Distribution at DC level, where effectively all elements share the DC link or bus.
- Like Advanced AC, DC architectures facilitate integration of energy storage and variable speed generation.
- Modern DC architectures are well suited to LV networks.
- Easy to synchronize, they deploy fault limiting electronics, fuses and off load disconnects to improve protection.
- Power electronics provide AC supplies for ship services etc.

ELECTRIC SHIP CONFIGURATIONS

Hybrid electric solutions are available in gear-mounted or direct drive, shaft-mounted electric motor configurations. They principally combine a hybrid of gas turbines or diesel engines with the mode selectable depending on speed, for example.

- In this way, hybrid solutions help to improve fuel economy and can provide the best low-noise performance.
- Power take-off is an energy-efficient option for weapons, sensors and ship service.
- A range of other hybrid configurations is available.



Submarine solutions

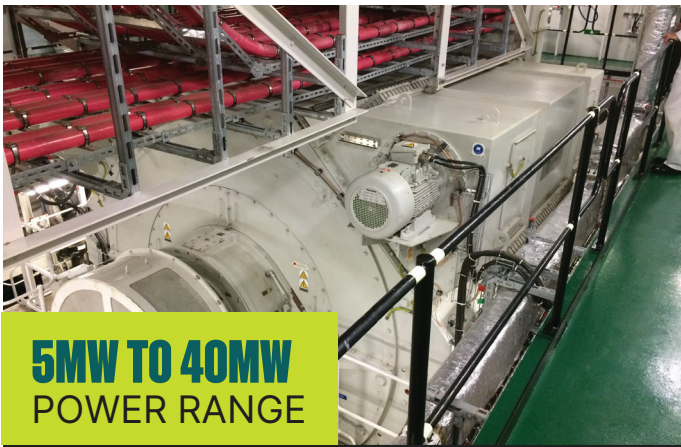
Power Conversion's specialist subsea system expertise is applied to SSK applications needing reliable, compact electric power and propulsion systems.

Design authority and technology capabilities include advanced, low acoustic signature electric propulsion motors, generators, energy storage and efficient DC distribution architectures and equipment.

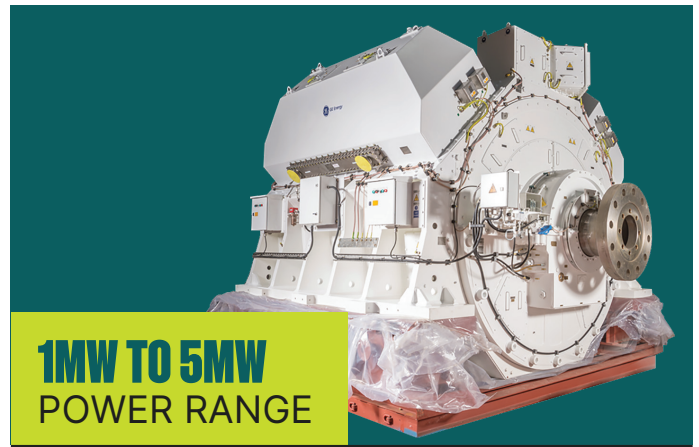
PROVEN TECHNOLOGIES

GE Vernova's Power Conversion business' leading naval power and propulsion technologies are designed and proven specifically for the high demands of naval applications and specifications.

- Shock-rated, proven in harsh environments.
- Powerful, variable speed operation for high efficiency.
- Reduced acoustic signatures, ideal for noise-sensitive applications, for example ASW frigates.
- Robust squirrel cage configuration with easily removable items for serviceability, improved maintainability and reliability.
- Certified by marine classification societies and built to IEC standard.



Power Conversion's Advanced Induction Motor (AIM) is a multi-phase, power-dense induction motor specifically configured for naval marine propulsion applications. **5-40MW** power range, proven on up to **80MW** propulsion system; speed range up to **200rpm**.



Compact Induction Motor (CIM) for naval marine electric and hybrid ships. Power Conversion's structured naval motor range for electric and hybrid-electric ship propulsion from **1MW to 5MW**.



VDM25000 Naval Marine Drive
Power Conversion's medium voltage VDM25000 drive is a modular, multiphase naval marine drive. With high power density, it is fully shock-rated and available as fresh-water cooled.



SeaPulse* MV3000 AFE Naval Marine Drive
Power Conversion's structured active front end (AFE), low voltage drive, available with air or water-cooled configuration for high performance electric and hybrid-electric naval ship power and propulsion.

For commercial specification naval or coast guard ships, our commercial marine systems are an excellent option.

PROVEN TECHNOLOGIES



High Voltage Switchboards

Navalised, shock proof, arc tested HV switchboards at 50kA rating and voltages up to 17.5kV.



Low Voltage Switchboards

Naval arc tested LV Switchboards at 85kA rating and voltages up to 690V.



Diesel Generator Alternator

Shock proof salient pole generators from 600-1800rpm, 3-14MVA and 690V to 11,000V.



Gas Turbine Alternator

Shock rated two pole turbo-generators, 3600rpm at power ratings from 23-46MVA and voltages from 4160V to 11,000V.



Active Harmonic Filter

Shock proof, low voltage active filter capable of suppressing 6 pulse and higher order harmonics using very high bandwidth anti-phase current injection from a navalised converter to ensure compliance with MIL-SRD 1399 P1/STANAG 1008 harmonic levels.



Passive Harmonic Filter

Shock proof, high voltage harmonic filters capable of ensuring compliance with MIL-STD 1399 P2 harmonic levels.



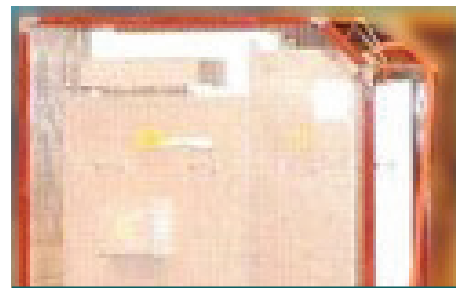
Transformer

Shock proof service and propulsion transformers.



NERs and HRGs

Shock proof neutral earthing resistors and high resistance grounding systems appropriate for grounding high power distribution systems from 690V to 11,000V.



DBRs

Shock proof dynamic braking resistors facilitating rapid shaft reversal on HV systems.



Propulsion Control System

Night vision compatible propulsion control incorporating telegraphs, limit indication and emergency overrides.



Power Management System

High performance, shock proof power management systems capable of handling the functions necessary to control and monitor highly dynamic naval IFEP and hybrid systems.

LAND BASED SYSTEM TEST AND EMULATION



At the heart of GE Vernova's Power Conversion Marine business lies a 4.5 acre, dedicated, full power, land-based test facility. The Marine Power Test Facility (MPTF) plays a crucial role in de-risking present and future power and propulsion technologies, putting them to work as integrated systems. It's used across product development and verification through to upgrade evaluation and complete, full-scale system test ahead of sea trials.

MPTF is the only commercial land-based facility in the world that is capable of full-scale testing of complete integrated naval power and propulsion systems from ship at up to 20MW scale.



- Available for GE Vernova and third party equipment.
- Integrating prime movers with electric ship systems.
- Opportunity to reduce schedules and costs through de-risking.
- Ship's crew training on real electric systems.
- Secure defense facility.
- New technology evaluation, including emerging cleaner energy sources.

CASE STUDY

Queen Elizabeth Class (QEC) Aircraft Carriers:

Providing the Ship's Electric Grid for the world's largest electric propulsion ship.

The Queen Elizabeth Class, HMS Queen Elizabeth and HMS Prince of Wales, are the UK Royal Navy's new aircraft carriers. The ships, more than three times the displacement of the Invincible Class they replaced, represent a step change in both size and capability.

This scaling-up came with significant energy demands, both for propulsion and for the ship's intense operational mission systems, as well as crew and vessel services.

The aircraft carriers would need a way of providing all this power as efficiently and safely as possible.

GE Vernova's Power Conversion team set out to design a configurable, scalable and integrated Electric Ship power architecture, pulling through proven equipment from other naval and commercial platforms, to help minimize cost and risk.



Twin island arrangement, with 50% of the propulsion and services supplied fwd, and 50% aft.

HV power and propulsion system arrangement:

- 2 x gas turbine (GT) & 4 x diesel generator (DG) electric alternators
- 4 x 11kV switchboard sections
- 4 x 20MW multi-phase Advanced Induction Motors (AIM)
- 4 X 20MW PWM multi-phase VDM25000 converters and 12 transformers
- 13 x ship's service transformers
- 3 x harmonic filters
- 2 x shore supply power connections
- Propulsion Control System including Power & Propulsion System control panels.
- Electrical power control and management system.
- System integration of GE Vernova's Ship Electric Grid and with other alliance partners.
- HV load bank for all setting to work and commissioning for the IFEP.

Solution Benefits and Outcome:

- Quiet and resilient, shock-capable electrical drive trains.
- Physical separation to suit build and survivability, connected only by electrical network (not rigid drive shafts).
- Enhanced availability, reliability and maintainability: Inherently robust power and propulsion plants.

Flexible, Frugal and Futureproof:

- Lowest number of installed prime movers compared with mechanical or hybrid drive ship systems.
- Easily adaptable to changing mission profiles, and future integration of low/zero emission power sources.
- Through-life cost savings in fuel and maintenance, due to running optimum number of prime movers at optimum loadings to match power demand.
- Large amounts of installed electrical power can accommodate significant future increases in combat system loads such as high-energy weapons and radar, with minimal impact.

Global Combat Ship Ultra-Quiet Hybrid Electric ASW Frigate

GE Vernova's technology delivers an extremely low noise signature, with high shock performance and action damage tolerance.

The Type 26 Frigate Global Combat Ship combines proven commercial technology with advanced military features to deliver state-of-the-art performance with the reliability of a mature solution.

Solutions

A hybrid electric propulsion system was selected, where the vessel operates on GE Vernova's electric propulsion for high efficiency but uses a direct engine drive for top speed. Power Conversion drew on its extensive experience from previous frigate, naval and commercial marine programs, and used advanced modeling and innovative design features, to deliver a highly robust electric ship system.

- Electric propulsion supplied by GE Vernova's Compact Induction Motors and SeaPulse* LV drives.
- 'Stealth' type technology propulsion – ultra-low acoustic signature.



- GE Vernova patented noise-quietening technology built directly into the electric motors themselves.
- Equipment de-risking through one shaft load and scale, integrated power and propulsion system testing located at GE Vernova's world-leading Marine Power Test Facility (MPTF) in the UK.
- Test and emulation plan identified over 300 real-life scenarios that the ship will encounter on op's to 'stress-test' systems ahead of costly sea trials.

U.S. Navy's Makin Island LHD-8 Landing Helicopter Dock

This Wasp-class ship is crewed by more than 1,000 sailors and can embark more than 1,600 Marines. Makin Island's mission is to transport and land ashore troops, materiel and supplies to support and sustain amphibious assault operations, including a substantial flight deck for fixed and rotor wing craft, so it has a broad range of power and propulsion demands.

Solutions

The electric propulsion system is, by some margin, the highest power system of its kind fitted to a vessel of this displacement.

- Launched in 2009, the USS Makin Island was the first U.S. Navy surface ship to be equipped with both gas turbines and a diesel-electric auxiliary propulsion system (APS), developed and delivered by GE.
- Enables a hybrid of different propulsion solutions to help maximize efficiency at different speeds and operating scenarios.



- While maneuvering, which is what she does for over 70% of her time, the ship's propeller shafts are powered indirectly by six diesel generators feeding two auxiliary electric propulsion motors.
- The electric propulsion uses SeaPulse MV3000 variable speed drives and high-performance electric induction propulsion motors, proven across naval and commercial marine applications.
- Now, it is being joined by two more vessels with identical propulsion systems. The PCU America LHA-6 Landing Helicopter Assault ship and an LHA-8, USS Tripoli.

CASE STUDY

Integrated Electrical Propulsion System for US Navy DDG 1000 destroyers

Futuristic generation of destroyers

The DDG 1000 Zumwalt-class destroyer is the U.S. Navy's most advanced multi-mission destroyer, and the U.S. Navy's first full electric propulsion ship.

Balancing proven capability with future-capable technologies, the navy engaged with industry to help meet its demanding needs. Designed for surface warfare, anti-aircraft and naval fire support, the ship's revolutionary technologies extend from its outward appearance to its on-board equipment. The innovative external appearance is significantly influenced by the wave-piercing tumble home hull form, the reverse slopes of the smooth deck, the superstructure and guns. This significantly reduces the radar cross-section, returning much less energy than a more hard-angled hull form.

The Navy designed the ship in this way because it wanted a stealth platform that could sail at 30 knots, and it required significant electrical power on board to support the all-electric ship and potential power available for future high energy weapons.



Solutions

The electric propulsion system is, by some margin, the highest power system of its kind fitted to a vessel of this displacement.

- Integrated electric, high voltage system
- U.S. Navy's first all-electric warship
- 78.5MW installed electrical power, 2 shafts in advanced electric, scalable architecture, providing power for all loads
- De-risking at Naval Ship Systems Engineering Station (NAVSSSES), Philadelphia
- Shock-rated, full naval specification systems
- Advanced Induction Motors
- Tandem motor configuration with three converter channels per motor
- Transformerless VDM25000 PWM converters
- MV switchboards
- Harmonic filters

Royal Norwegian Navy Support Vessel (LSV)

Powered by GE Vernova's Energy-Efficient Hybrid Propulsion Drive Technology.

Hybrid-electric propulsion systems, like that supplied by GE Vernova to the Norwegian LSV, KNM Maud, combine both electrical and mechanical equipment to turn the ship's propellers throughout the speed operating range. The Norwegian LSV has two independent propeller shafts each driven via a gearbox by either a large propulsion diesel or a relatively small electric motor. When the ship is operating at moderate or low speeds, the propeller shafts are turned using GE Vernova's electric motors with speed control for each motor being provided by the use of a low-voltage variable speed drive. The electrical power for the motors is supplied from the generators used to supply the remainder of the ship's services. This reduces the number of generators in operation and often allows those that are in use to be run at a more efficient operating point.

When the ship is required to operate at higher speeds, the main propulsion diesel engines are started and the propellers are now turned, via the gearboxes, by these engines. The propulsion motors now can be operated in the opposite sense as generators, using a small amount of energy from the propulsion engines to supply electricity to the ship's services. This in turn allows the ship service generators to be shut down once again reducing overall operating hours of the ship's diesels and saving maintenance cost.

This hybrid configuration is a versatile propulsion solution and is particularly suited to the fluctuating operational scenarios encountered by naval warships and auxiliaries. Using electric propulsion motors powered by the ship's generating sets to turn the propeller saves fuel, reduces emissions and reduces maintenance costs of the main engines, which can be shut down. The generating sets are running to meet other electrical needs of the ship anyway, so the overall number of hours run by the various diesel engines onboard is reduced.



In addition to electric propulsion motor and variable speed drive equipment, GE Vernova's Power Conversion business also supplied switchboards, alternators, cargo pump drives and the bow thruster motor and drive. Our system engineers worked closely with the shipyard, the NDLO and other equipment suppliers to ensure that the electrical power system was fully integrated to meet operational requirements.



TOTAL LIFECYCLE SUPPORT

With a comprehensive network of service engineers and technicians, GE Vernova is uniquely positioned to provide the knowledge, experience and skills to help you protect your assets, maintain critical processes, lower risk and increase productivity.

We deliver original equipment spare parts around the world and we repair, refurbish and upgrade your systems with our latest technology. GE Vernova offers risk protection through contractual services based on system experience and sophisticated application calculations.

- Expertise of our integrated system design services; advice on configuration options, performance and cost of ownership.
- Fleet and asset performance management – mission-ready.
- Global support, dedicated remote monitoring and diagnostics.

ABOUT GE VERNOVA'S POWER CONVERSION NAVAL BUSINESS

GE Vernova supports naval missions by delivering flexible and reliable solutions for integrated, full electric and hybrid propulsion. Vessels range from high-capability warships to the latest fast fleet support and coastguard ice-patrol. GE Vernova's powerful electrical networks are capable of supporting a ship's major requirements, including propulsion, high-power sensors, service loads and pulse power for defense systems. Options include full-electric or hybrid-systems, in geared or direct-drive configurations. GE Vernova's dependable technologies are proven on fully shock rated naval applications and commercial fleets.

www.gepowerconversion.com

To find out more:
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GEA35120A 08/2023



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