SeaGreen

Energy Storage Systems for Marine Applications

gepowerconversion.com

Total lifecycle electrification, energy management and digital partner to the Marine industry

Applying deep expertise. Advancing smarter solutions.

Modern marine power systems require solutions to meet the industry's challenging performance criteria, classification society rules and regulatory constraints. These requirements challenge the marine industry to evolve, in search of improved methods of vessel design and operational performance, including reduced emissions and fuel efficiency. Vessels with variable operating profiles and fluctuating loads, benefit from the ability to store excess energy onboard, with instant access to and rapid replenishment of the store to ensure energy usage is improved.

Energy and system integration expertise

GE's team of SeaLab marine engineering and applications experts are on hand to advise you on the best and most cost-effective way to integrate SeaGreen* ESS into your current fleet or new build configuration, customizing it to suit the functionality you need for your vessel operations.

The addition of energy storage to a vessel's power and propulsion system offers many advantages. To get the most out of this technology it is essential to consider not only the most appropriate energy storage media but also how best to integrate in to the electrical system.

Connecting a SeaGreen* Energy Storage System (ESS) directly to the main generation system via a dedicated transformer is the simplest way to enhance the ESS configuration and maximize its benefits. Through its DC to AC inverter, the ESS can provide energy to anything connected to the main generation system and becomes a flexible and seamless part of the vessel's power network.

Some specialist vessel equipment benefits from a dedicated energy store. For example, connecting the ESS directly into the DC link of thruster drives or a drilling system. This can be a cost effective option if the energy store is only required for a specific vessel system.

In today's competitive environment, and with new emissions regulations and airborne noise restrictions planned, there is considerable interest in retrofitting energy storage to existing fleets. This can help to increase range of operations, enhance day rates and improve availability performance. GE's SeaGreen* containerized ESS offers a 'plug and play' solution to upgrading your vessel.

It is also important to consider the implication of energy storage on the vessel's power management and other control systems. GE's vast experience of integrated hybrid power, vessel control and dynamic positioning (DP) systems means the ESS benefits are engineered for your specific application and vessel duty cycles. Energy storage can be configured to be autonomous with no modifications to the DP and automation or can be fully integrated as a static prime mover, depending on the application.

BATTERIES

Batteries are a "here and now" energy storage technology and are widely used in hybrids. Ideally suited to applications that require support in the "minutes" range, batteries are generally considered for applications such as load levelling, static support and short duration operations on pure electric vessels like ro-ro ferries. Even battery energy storage has options for different battery chemistries (such as Lithium Ion). Each has different performance attributes to consider - lifecycle limits, charge and discharge rates, environmental parameters, etc.

SUPERCAPACITORS

Supercaps are also currently available and have advantages over battery solution in applications that are highly cyclic as they have a much longer life expectancy in terms of number of cycles. Supercapacitors are best suited to providing energy in the very short timeframe (seconds) and so are generally applied to applications such as heave compensation and other highly cyclic operations.

FLYWHEELS

Flywheels are a mechanical method of storing energy through rotating inertia and so are not so susceptible to environmental factors and output does not degrade with age or frequent charge/discharging cycles. Quick to charge and discharge flywheels are generally considered for short, pulse power applications. However, one of the challenges for flywheels is ensuring the mechanical integrity and thus safety of masses spinning at extremely high speeds on marine vessels.

FUEL CELLS

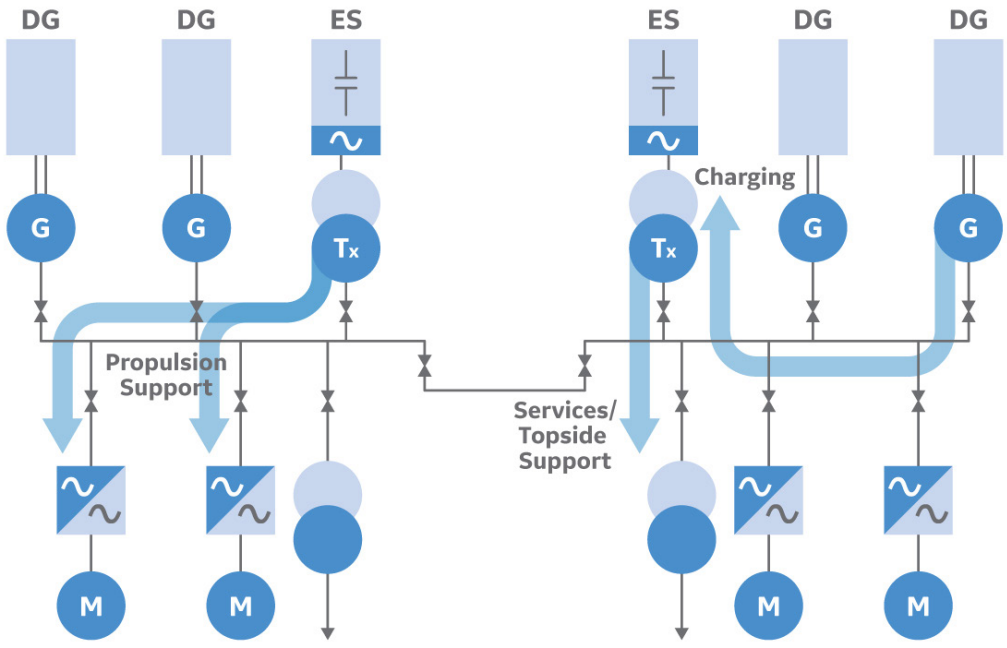
There are a variety of fuel cell technologies for marine applications currently under development (e.g. hydrogen, nitrogen etc.). Fuel cell technologies aim to provide a longer duration (hours) and cleaner alternative to burning fossil fuels by taking in commonly occurring elements as the energy source and exploiting a chemical reaction to produce electricity, leaving only harmless by-products.

GE Power Conversion and Nedstack, a leading fuel cell manufacturer, are collaborating on developing hydrogen fuel cell systems for powering zero-emission cruise vessels. This partnership brings together GE's recognized expertise in cruise electrical power and propulsion solutions plus system integration capability, with Nedstack's extensive experience in megawatt-scale hydrogen fuel cell technology. The result will be highly efficient fuel cell solutions that enable a zero-emission cruise industry.

GE's **SeaGreen*** Battery Energy Storage System (ESS) is ideal for both new build vessels, and containerized for a retrofittable solution. Engineered for vessel types requiring cycling operations, **SeaGreen*** Battery Energy Storage System is an integrated, scalable, smart power and energy system which includes options for both AC or DC architectures. **SeaGreen*** manages energy sources according to load demand enabling marine operators to improve energy usage whilst providing continuity of operations, increased efficiency and reduced emissions.

Comprehensively tested at GE's Marine Power Test Facility (MPTF) in the UK, it is part of GE's range of hybrid and electric vessel systems with significant references across marine offshore, naval, transport and passenger sectors.

1MW Battery Under Integrated System Test at the Marine Power Test Facility, UK.



Different Power Flows into and out from the Energy Store


Continuity of operations
Increased efficiency & resilience
Reduced emissions

Operating modes

GE's **SeaGreen** Energy Storage System (ESS) is configured to operate in any or all of the following five operating modes. Some modes can be selected in parallel, such as Dynamic Support and UPS, and tailored to suit a diverse set of requirements, from emission reduction to ultra-high energy pulse applications.

UPS	POWER RESERVE	DYNAMIC SUPPORT	ENERGY STORE ONLY	HYBRID BOOST
5 - 20 MINUTES	**5 - 20 MINUTES**	**1 MINUTE**	**30 MINUTES**	**>30 MINUTES**
UPS mode enables continuity of operations, increases availability, improves resilience.	Continuity of operations through blackout avoidance, improves efficiency, reduces opex (fuel & maintenance), reduces emissions.	Improves responsiveness, improves efficiency, reduces opex (fuel & maintenance), reduces emissions.	Improves efficiency, reduces opex (fuel & maintenance), eliminates emissions, reduces noise.	Improves efficiency, reduces opex (fuel), reduces emissions.

Table above depicts standard modes and typical durations only.

SELECTING YOUR SEAGREEN ESS PACKAGE

Our operating modes guide is the starting point to selecting a SeaGreen ESS package which will provide the most benefit for your vessel operations and duty cycles.

Packages can be combined and customized based on what you need, and the vessel layout.

Fundamentally energy storage options are based around the level and duration of power required. GE's SeaLab engineering team can work with your team to discuss operating profiles and configurations.

SWITCHING BETWEEN OPERATING MODES

If you opt for a SeaGreen ESS with more than one mode, simple on-vessel mode selection is provided.

UPS mode is usually enabled when the energy store is on line, and the convertor acts on loss of generators to initiate the ESS.

Other modes are enabled or disabled as required manually, or in simple systems can be pre-set.

Like a rotating prime mover, the energy storage can permanently be switched off either locally or remotely, when the circuit breaker will open. This is how all energy storage modes including UPS are inhibited.

AVAILABILITY & CHARGING

In Power Reserve Mode, the energy store will maintain its charge automatically to a pre-set level to suit the application.

In Dynamic Support Mode the charge in and out of the energy store is self-determined by the ESS within the range and capacity of the converter and batteries.

The Power Management System (PMS) can provide an optional 'Charge Inhibit' signal which prevents the energy store from taking power from the system to recharge itself.

If the energy store is depleted, and the charge inhibit signal is not present, then the energy store will charge at a pre-set maximum rate, typically 10% of the converter rating until it is fully charged.

There is an optional signal for 'Fast charge' from the PMS, that allows a pre-set higher level of charging if there is sufficient generating capacity.

Charging, at the low or higher rate allows the energy store to be considered as a consumer load on the system, which can be inhibited if required.

Where multiple modes are employed in parallel on a system, the energy store can prioritize charge to help ensure, for example, that there is enough energy for blackout prevention even if dynamic support is currently being undertaken.

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UPS MODE

APPLICATION Although complete vessel blackouts are rare with modern diesel electric propulsion systems and their associated protection strategies, they can of course still occur. A blackout can be hugely disruptive to vessel operations and in some instances even cause safety issues or damage, so we share in the marine industry's focus on reducing blackout problems.

OPERATION In the event of loss of engine power from the ship's power system, the ESS takes over provision of power. Connected to a bus and ready to go in stand-by, the ESS continuously monitors voltage, frequency and other signals, immediately initiating if there is no engine power output and seemlessly taking over supply of power. With an energy store appropriately sized, a blackout on that section is avoided while power from the prime movers is being restored.

SUPPORT DURATION Typically 5-20 minutes.

POWER RESERVE MODE

APPLICATION It is normal for a vessel performing Dynamic Positioning (DP) or other critical operations to run an excess of diesel engines to provide a "spinning reserve" of power that remains available, online and ready to take over in the event of a failure of any engine or engines contained in a redundancy group. In addition to increased emissions, this excess engine capacity incurs significant, avoidable opex from its extra fuel burn and maintenance. These can be made worse when back-up engines run inefficiently at low-load.

OPERATION Similar in functionality to the UPS mode. As such the ESS is not normally in operation but continuously monitors bus frequency and in the event that a sudden drop is detected the ESS will immediately initiate to deliver power to support the remaining engines online. The ESS should be appropriately sized to support anticipated loading until other engines can be started and brought online or the PMS takes the necessary actions to reduce the load to within the capability of the connected generation.

SUPPORT DURATION Typically 5-20 minutes.

DYNAMIC SUPPORT MODE

APPLICATION This mode supports a range of applications where the vessel would benefit from improved response to changes in power demand:

Dynamic Responsiveness - Often the responsiveness of a vessel to sudden changes in load is limited only by the rate at which the mechanical power plant can pick it up. For example ramp rates within thruster drives systems are limited to the ramp rate of the engine. Therefore the capability of the vessel to respond to sudden changes in environment is impaired and the engines suffer additional thermal and mechanical stresses and strains associated with their attempt to respond.

Load Levelling - The rate at which engines consume fuel is greatly impacted by the frequency and magnitude of load swings, in much the same way as pressing the accelerator hard in your car increases the fuel consumption, especially in stop-start traffic. So the vessel benefits from the ability to smooth load demands on the engines, enabling them to operate as efficiently as possible, and reducing the thermal and mechanical stresses of frequent cycling.

Peak Shaving - Similar in concept to load levelling by targeting applications where the load demand is highly cyclic (e.g. heave compensation). It is often the case that these predictable peak power demands necessitate having additional generation online continuously as it is not practical or possible to stop and start the engine just in time. Thus for the majority of time the presence of an additional engine online just to manage peak power demands results in overall lower efficiency of all engines, while ramping up unnecessary running hours, fuel and maintenance costs and emissions.

OPERATION For normal dynamic responsiveness applications and load levelling the ESS will be configured to take up sudden load increases faster than the mechanical engine plant thereby allowing ramp rates and other system dynamics to be improved for vessel performance and the diesel engines can then slowly take over the demand. If the increased load duration becomes prolonged and the ESS becomes depleted it will be necessary to initiate the starting of an additional engine or to shed load in a controlled way through the PMS.

Where cyclic loads are predictable, or where large loads are about to be switched on, the PMS or the load system can be configured to send advance warning to the ESS, depending upon the speed at which support will be required.

SUPPORT DURATION Typically up to 1 minute.

ENERGY STORE ONLY MODE

APPLICATION With an ever increasing focus on fuel and noise emissions and other environmental factors some vessel owners want the option to run on pure electric energy sources (i.e. no burning of fossil fuels). This may be either for a defined period of operation (e.g. in and out of harbor) or for the entire operation (e.g. RO-RO ferry). For naval applications electric mode also provides reduced vessel acoustic signatures for stealth-type operation.

OPERATION The ESS is either the sole energy source, or at the operator's initiation the system smoothly transfers load from the engines to the ESS before shutting the engines down. It is similar in functionality to the UPS mode with the exception that initiation is proactive and for a longer duration; for this reason typically a larger energy storage device is integrated.

SUPPORT DURATION Typically up to 30 minutes.

HYBRID BOOST MODE

APPLICATION In order to reduce engine running hours, and help ensure operation at the optimal point on the fuel curve, the ESS can be used to supplement engines running, to avoid starting another prime mover. For example if the energy demand was too low for three engines, but just too much for two, using the scalable ESS in tandem with one or more engines is effectively like being able to use a fraction of a prime mover. It improves load on the engines that are running, providing a top up for the balance of power required.

OPERATION The system uses the battery energy to provide continuous power, to minimise the running engines, then when the battery is below a certain level of charge, an additional engine starts for a short duration, and provide the ship's power and recharges the ESS. When charged, the engine would stop and the cycle would repeat, potentially many times during a journey.

SUPPORT DURATION To suit application requirements. Typically >30 minutes.

Helping to keep your fleet running smoothly – for the long term

Complete service offering

We understand the vital importance of vessel availability - and our service focus keeps us actively engaged, both when things are going right and if they were to go wrong. From hotline, rapid response, and remote diagnostic packages to comprehensive multi-year contracts, you'll find marine services partnerships uniquely structured to increase asset availability and process productivity across your vessel's every lifestage.

COMMISSIONING Launching new vessels—and crews— with confidence. The marine services commissioning and training teams help your assets go into active service functioning consistently and efficiently, and your people have the hands-on, real-world skills to operate and maintain them.

MAINTENANCE Solving problems, no matter what or where they are. Our Visor Asset Management remote monitoring and support solution, and global network of local service centers —equipped with spare parts and field engineers—ensure you'll have the resources to prevent and correct issues on even highly complex systems deployed in inaccessable locations.

MANAGEMENT Keeping your vessel up-to-date, for the long haul. The marine services overhauls, modernization and upgrades, and obsolescence management teams work in close cooperation with customers to ensure proactive lifecycle planning and trouble-free execution, so your assets perform better, longer.

We offer a wide range of after-sales service and support packages tailored to a single vessel or to an entire fleet . These packages are delivered via a world-wide network of support bases. Some of the key benefits of a GE support package are:

- Single point of contact
- Reduced call-out rates
- 24/7 support
- Rapid mobilization of engineers
- Routine maintenance visits
- Dry docking support
- Training
- System health checks
- Spares management
- Lifecycle management
- Digital Asset Performance Management solutions

GE also provides managed system upgrade paths for its 'legacy' systems and has significant experience of replacing systems from other manufacturers with a minimum of disruption to ship's infrastructure.

About GE Power Conversion

GE's Power Conversion business, a business unit of GE Power, applies the science and systems of power conversion to help drive the electric transformation of the world's energy infrastructure. It does so by making and delivering advanced motor, drive and control technologies that evolve today's industrial processes for a cleaner, more productive future. Serving specialized sectors such as energy, marine, renewables and industry, through customized solutions and advanced technologies, GE Power Conversion partners with customers to maximize efficiency.

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