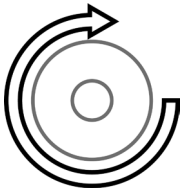


5.9 Energy Storage Solutions

Energy Storage Systems are increasingly used to improve the energy efficiency and operational expenses in several vessel types and operations.

THE USE OF ENERGY STORAGE CAN BE DIVIDED INTO THE BELOW MAIN APPLICATIONS:



Spinning Reserve

Energy Storage System is connected and running but not charging or discharging energy into the system. On loss of generating capacity it steps in to take the load for a predefined period of time. If other functions are activated simultaneously, this function ensures that sufficient energy reserve is left in battery. The spinning reserve function allows operation with fewer generators online, resulting in more optimal engine loading with improved fuel efficiency and reduced accumulated running hours.

Benefits include:

- Improved safety and availability
- Reduced fuel consumption and engine maintenance
- Reduced Noise

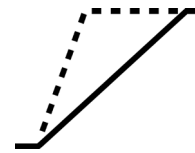


Peak Shaving

Energy Storage System absorbs load variations in the network so that engines only see the average system load. The system will level the power seen by engines and offset the need to start new engines. Peak shaving will improve fuel efficiency and reduce engine running hours.

Benefits include:

- Reduced fuel consumption and engine maintenance



Enhanced Dynamic Performance

Energy Storage System absorbs sudden load changes and then ramps the change over on running engines. If peak shaving is used, then this function is automatically included. It provides instant power in support of running gensets. The system also enables the use of «slower» engines, like LNG/Dual Fuel engines in dynamic power applications.

Benefits include:

- Reduced fuel consumption
- Enabler for “slower” sources like LNG and fuel cells



Battery System Introduction

The tremendous technological and cost development of the lithium-ion battery has been the enabler for long lasting and cost efficient energy storage on board ships.

The battery system is build up from the cell as the below example:

- Cell
Common for all. One cell
- Module
A set of series-connected cells or cell groups. Normally equipped with a module BMS
- String , Rack, Pack
A set of series-connected modules to desired system voltage incl. rack BMS
- Bank, Array
Set of battery racks connected to common DC bus bar with associated DC breaker and system BMS



UPS

Same as spinning reserve, but on a local level in a sub-system like a thruster or drilling drive. The enhanced ride through will create an higher power system availability and new ways of achieving higher ERN numbers. The energy storage system can give UPS like functionality for all or portions of a power system.

Benefits include:

- Improved safety
- Reduced fuel consumption and engine maintenance

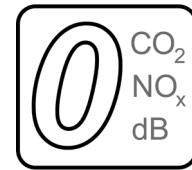


Strategic Loading

Energy Storage System interacts with the power system to optimize engine fuel efficiency. ES media is charged and discharged in such a way that the operating point of online generators is optimized so that power is only generated at peak efficiency and lowest cost.

Benefits include:

- Reduced fuel consumption



Zero Emissions Operations

Zero emission operations can be used for fully battery electric vessels or Hybrid vessels. Energy Storage System powers the system so that engines can be turned off. This enables things like zero-emissions in harbor and zero emission port calls. This also enables i.e. exploration cruise and other passenger vessels to access protected areas.

Benefits include:

- Quiet engine room
- Zero emission operation

Integrating Energy Storage to the System

The energy storage system may be integrated to the power system in various solution dependent of the application.



Integrated to an Onboard DC Grid System or DC Link

The battery is connected to a DC link in the power system through a DC/DC converter. (Onboard DC Grid or DC link in a thruster drive or drilling drive). The DC /DC converter provides extremely fast and accurate control of the battery power in order to realize functional control tasks. Compared to AC integration of batteries DC provides more compact solution and faster control.

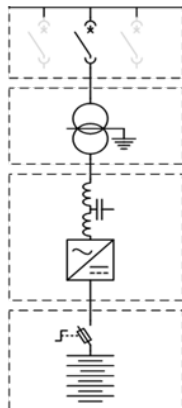


Direct Online (DOL)

The battery is connected directly to a DC link in the power system through. (Onboard DC Grid or DC link in a thruster drive or drilling drive). Since the battery directly it will define the voltage of the DC link, hence all other equipment must be rated for the voltage span of the battery. (Up to 25% variation)

Main advantage of DOL solution is energy efficiency, however the disadvantage is less control of the power flow.

This solution is typically used for Ferries in zero emission operations



Integrated to an AC System

For AC Power system the battery has to be connected through a DC/AC converter and a transformer. This can be used in both low voltage and high voltage applications.

The converter and transformer must be dimensioned for the lowest battery voltage, meanwhile the converter must be able to handle the maximum battery voltage. This typically large de-rating of the converter, hence relatively large converters.

Containerized energy storage systems

Complete battery storage systems for retrofit and newbuilt vessels

ABB offers a turnkey hybrid power solution which improves power plant safety and availability. The solution reduces fuel consumption and pollutant emissions, improves crew comfort and reduces noise, and reduces engine maintenance.

What is containerized ESS?

ABB's containerized energy storage system is a complete, self-contained battery solution for large-scale marine energy storage. The batteries

and all control, interface, and auxiliary equipment are delivered in a single shipping container for simple installation on board any vessel. The standard delivery includes batteries, power converters for shore connection and connection to the ship's power system, Energy Storage Control System, cooling and ventilation, and fire protection. The solution is ideal for both retrofit and newbuilt applications.

— Containerized energy storage solution is easy to install e.g. on top deck of vessels



How does containerized ESS work?

The energy storage system stores energy when demand is low, and delivers it back when demand increases, enhancing the performance of the vessel's power plant. The flow of energy is controlled by ABB's dynamic Energy Storage Control System. It enables several new modes of power plant operation which improve responsiveness, reliability, safety, and fuel consumption. The system also provides a shore connection with frequency conversion, allowing the vessel to connect to 50 or 60 Hz shore power.

What are the benefits?

The energy storage system supports the following functionality:

- Peak shaving: Level power seen by engines and offset need to start new engines. Benefits include reduced fuel consumption and engine maintenance.
- Enhanced dynamic performance: Instant power in support of running engines. Benefits include reduced fuel consumption and enabler for "slower" sources like LNG and fuel cells.
- Spinning reserve: Backup power to running generators. Benefits include improved safety and reduced fuel consumption and engine maintenance.

Significant results

According to the joint industry project Hybrid Power, fitting a typical offshore support vessel with energy storage can result in significant reduction in fuel consumption and pollutant emissions, as well as economic benefits through reduction of operating expenses.

System integration

Drawing on our decades-long experience as an industry leader in marine power systems, ABB takes the uncertainty out of marine energy storage. ABB's holistic approach includes complete mechanical, electrical, and control design, resulting in a simple, standardized package. The complete system is fully tested before delivery, allowing quick and easy integration once it is installed on board the vessel. The streamlined mechanical, electrical, and control interfaces require minimal work to integrate into any vessel, new or old.

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ABB's holistic approach includes complete mechanical, electrical, and control design, resulting in a simple, standardized package.

ABB Ability™ for the marine industry

ABB Ability is our unified, cross-industry digital capability. ABB Ability provides the services and solutions that integrate systems on land, sea and air. From collaborative operations to remote monitoring, motion forecasting and energy management, ABB Ability enables vessel operators to know more, do more, and do better, together.

With our ABB Ability Collaborative Operation Centers we enable next generation vessel and customer onshore operations. We bring advanced analytics, portals, and the possibilities of digital twin technology, to drive the digitalization of ship operations.

ABB's containerized energy storage system includes monitoring, diagnostics and data logging of the batteries and converters through ABB Ability Marine Remote Diagnostic System. The on-board data logging computer is ready for connection to ABB Ability Collaborative Operation Centers and ABB Ability Marine Fleet Portal, enabling global access by the vessel's owner and by ABB's experts when required.

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Typical specifications

Batteries

Energy capacity	565 kWh
Battery type	Lithium ion
Cooling	Air or fresh water

Power converters

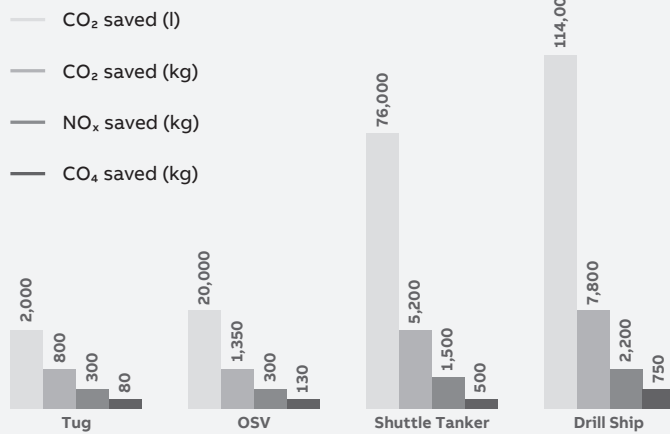
Type	ABB ACS800
Cooling	Fresh water

Container

Dimensions	20' container (6050 x 2862 x 3100 mm)
Mass with equipment	23 000 kg
Cooling	Fresh water
Ambient temperature range	-20°C / +40°C
Internal climate control	Air to air water heat pump
Safety equipment	Smoke detectors, manual alarm call point, PA/GA loudspeaker
Fire fighting	Water mist
Marine class approval	Yes - as deckhouse

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Emissions cut by hybrid operations enabled by energy storage solutions

Reductions in emissions as a result of hybrid vessel operations



Reductions in emissions as a result of hybridization in thousand gallons (1 gallon = 3,785 liters)

