



Onboard DC Grid

The newest design for marine power and propulsion systems

JAN FREDRIK HANSEN, JOHN OLAV LINDTJØRN, TOR-ARNE MYKLEBUST, KLAUS VÄNSKÄ – Think of a Mac from Apple, a Le Corbusier chair, a Frank Lloyd Wright house. All are designs that are clean, elegant, streamlined. All are also designs that took an existing element and created something innovative. ABB has done just that with its Onboard DC Grid for electric power distribution, creating the most flexible marine power and propulsion system to date. The system merges the various DC links throughout the vessel and distributes power through a single 1,000 V DC circuit, thereby eliminating

the need for main AC switchboards, distributed rectifiers and converter transformers. The Onboard DC Grid combines the best of both AC and DC components and systems, is fully compliant with rules and regulations for selectivity and equipment protection, can be used for any electrical marine application up to 20 MW, and operates at a nominal voltage of 1,000 V DC. The best part: ABB's Onboard DC Grid increases a vessel's energy efficiency by up to 20 percent and reduces the electrical equipment footprint and weight by up to 30 percent.

In designing the new system, ABB looked at the entire power delivery chain of energy conversions on marine vessels and identified a case for using DC distribution rather than the traditional AC system.

Two longstanding and crucial principles have been carried over from the traditional AC distribution system to form the framework of the Onboard DC Grid philosophy: equipment shall be protected in case of failures and proper selectivity¹ shall be ensured in such a way that safe operation is maintained after any single failure.

Advantages of DC distribution in certain cases include lower overall losses and fewer problems with harmonic distortion. Yet historically there have been challenges with DC distribution, primarily revolving around how full selectivity and equipment protection can be achieved in ways that are similar to AC distribution. AC currents are by nature simpler to interrupt because of their natural zero crossing every half cycle. DC circuit breakers exist but are more complex, larger and more expensive than comparable AC circuit breakers.

ABB overcame these challenges by breaking with the classic protection philosophy, where selectivity is achieved through an arrangement of coordinated circuit breakers, and instead capitalizing on the opportunities afforded by power electronic components in the Onboard DC Grid system.

Power distribution and configurations

In traditional electrical propulsion systems, variable frequency drives typically account for more than 80 percent of the installed power. At its simplest level, the Onboard DC Grid concept is a reworked and distributed multidrive system where distributed rectifiers are eliminated (Figure 1).

The new system merges the various DC links around the vessel and distributes power through a single 1,000 V DC circuit, thereby eliminating the need for main AC switchboards, distributed rectifiers and converter transformers (Figure 2). All electric power generated is fed either directly or via a rectifier into a common DC bus that distributes the electrical energy

1a Platform supply vessel with Onboard DC Grid



1b AC to DC transformation of a generic electric propulsion system

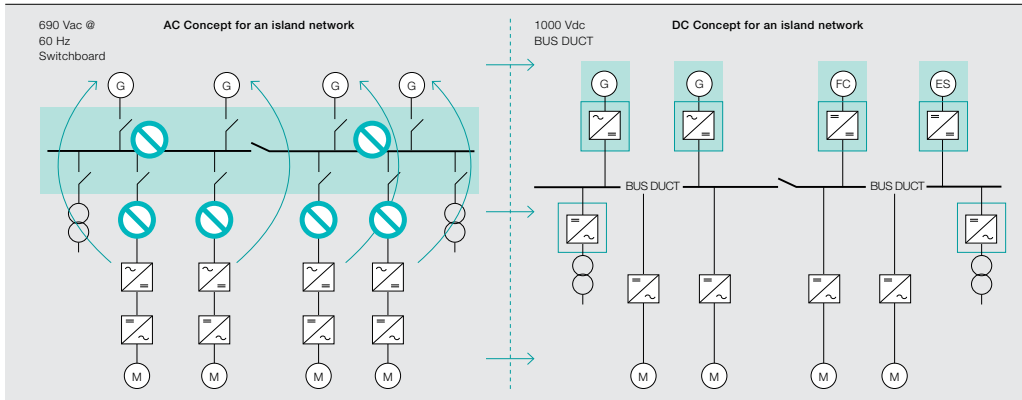


The new system merges the various DC links around the vessel and distributes powers through a single 1,000 V DC circuit.

Title picture

Marine offshore support vessels are excellent candidates for the Onboard DC Grid

2 AC to DC transformation of a generic electric propulsion system



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to the onboard consumers. Each main consumer is then fed by a separate inverter unit. When an AC distribution network is still needed, for example with a 230 V hotel load, it is fed using island converters, developed by ABB to feed clean power to these more sensitive circuits. Additional converters for energy storage in the form of batteries or super capacitors for leveling out power variations can be added to the DC Grid.

The system has been remodeled in such a way that most of the well-proven products used in today's electric ships such as AC generators, inverter modules and AC motors can still be used.

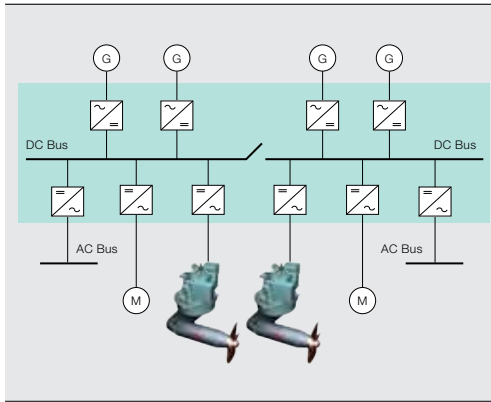
The Onboard DC Grid can be configured in several different ways. With a centralized approach all converter modules are located in one or multiple lineups within the same space that the main AC switchboards used to occupy (Figure 3).

With a distributed approach, the various converters can be placed where it suits the vessel operation or design best (Figure 4). The AC generators can have either integrated or stand-alone rectifiers installed in cabinets. As a result of the novel approach to protection, the volume of components that, by law, must be installed in the main switchboard room is drastically reduced. This affords the vessel designer a new level of freedom in designing the electrical power system around the vessel function, increasing the vessel functionality and value.

Protection and safety

With the main AC switchboard, AC circuit breakers and protection relays omitted from the new design,

3 Onboard DC Grid, multdrive approach

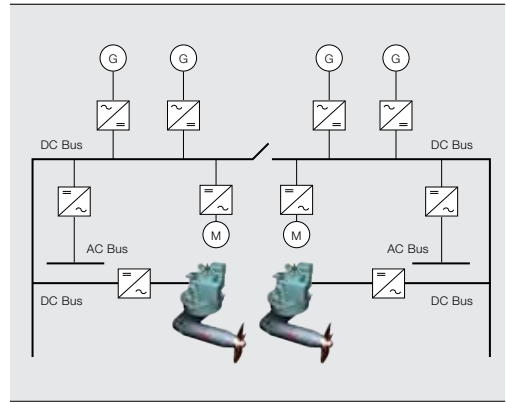


a new protection philosophy that fulfills regulatory requirements for selectivity and equipment protection is essential. Proper protection of the Onboard DC Grid is achieved through a combination of fuses, isolating switches and controlled turn-off of semiconductor power devices. Since all energy-producing components have controllable switching devices, the fault current can be interrupted much faster than would be possible with traditional circuit breakers and their associated protection relays.

In case of a serious fault in a module, fuses are used to protect and isolate inverter modules just as with current LV frequency converters. In addition, input circuits separate the inverter modules from the main DC bus and afford full control of reverse power, both in fault and normal conditions (as, for example, in propeller braking mode). This means that faults on a single consumer will not affect other consumers on the main DC distribution system. In the event of severe faults on the distributed DC bus, the system is protected with generators by means of a controllable thyristor rectifier, which also doubles as a protection device for the generator. Isolator switches are installed in each circuit branch in order to isolate faulty sections automatically from the healthy system.

In close cooperation with Det Norske Veritas, a global organization that provides classification and risk assessment services to the maritime industry, ABB has ensured that the Onboard DC Grid system philosophy meets or exceeds the demands of current rules and regulations. Fault currents can be controlled in as little as 10 ms to 20 ms, resulting in a drastic reduction in the DC Grid's fault energy levels when compared with traditional AC protection

4 Onboard DC Grid, distributed approach



circuits where fault durations can reach up to 1 s. This low-energy fault protection scheme, combined with the new flexibility in designing generator parameters, allows the Onboard DC Grid system to be used for installed power up to 20 MW.

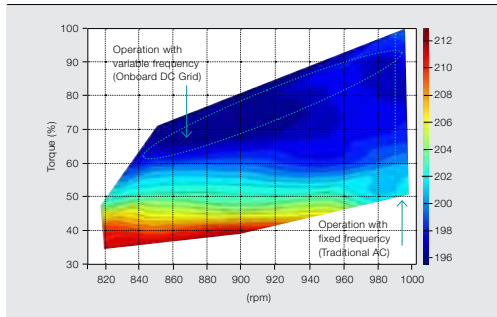
Efficiency with fuel and space

The DC Grid concept utilizes well-proven AC generators and motors, but allows for increased efficiency because the system is no longer locked to a specific frequency (usually 60 Hz on ships), even though any 60 Hz power source may still be used. The new freedom of controlling each power consumer independently opens up numerous ways of optimizing fuel consumption.

When operating marine combustion engines at constant speed, the fuel consumption is lowest in a very small operating window, typically around 85 percent of rated load. With the introduction of variable-speed operation of the engine, this window of optimal efficiency can be extended as far down as 5 percent, depending on the engine (Figure 5). If the engine is operated at loads below this, the engine efficiency remains significantly higher than that of the traditional fixed-speed equivalent. The end result is that a typical offshore support vessel can achieve fuel savings of up to 20 percent (Figure 6).

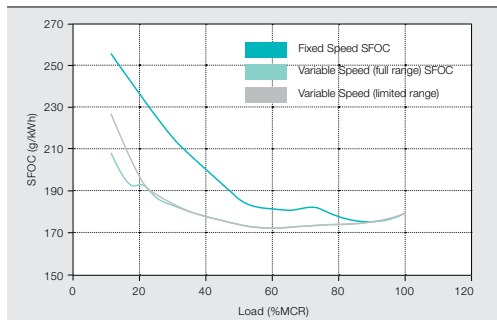
By eliminating the bulky converter transformers and main switchboards previously needed with the traditional AC system, the Onboard DC Grid also reduces the footprint of the electrical equipment used (Figure 7). This creates more space and provides greater flexibility in the positioning of system components in the vessel. In addition, the system enables simpler

5 Engine fuel tests at variable speed (color scheme indicates specific fuel oil consumption (SFOC) in g/kWh. University test engine)



Test results are of fuel consumption as a function of applied torque and RPM for a small test engine at Helsinki University. Results show that it is possible to run this type of engine with the lowest possible fuel consumption at least down to 50 percent leading.

6 Engine fuel characteristics at variable speed (color scheme indicates specific fuel oil consumption (SFOC) in g/kWh)



Further analysis has been done, in cooperation with an independent engine manufacturer, on a medium speed engine range typically used in OSV vessel powerplants.

7 Benefits of the Onboard DC Grid

- More functional vessel layout through more flexible placement of electrical components
- Reduced maintenance of engines by more efficient operation
- Improved dynamic response and maneuverability
- Increased space for payload through lower electrical footprint and more flexible placement of electrical components
- A system platform that allows “plug and play” retrofitting possibilities to adapt to future energy sources
- Up to 20 percent fuel savings

integration of supplementary DC energy sources such as solar panels, fuel cells or batteries into the ship’s DC electric systems, creating scope for further fuel savings.

The reduced weight and footprint of the installed electrical equipment will vary depending on the ship type and application. One comparison using a distributed variant of the Onboard DC Grid system instead of the traditional AC system for a platform supply vessel (PSV) reduced the weight of the electric system components by 25 percent from 115 to 86 metric tons.

Dynamic positioning vessels

The variable power consumption of anchor handling vessels and offshore support vessels make them very good candidates for the Onboard DC Grid system (Figure 8). The new concept helps solve the traditional fuel efficiency challenge faced in dynamic positioning (DP) operations. DP vessels often need to run several diesel generators in parallel due to redundancy considerations. This means that the connected diesel engines spend most of their running hours at relatively low loads, where fuel efficiency is significantly lower than at the optimal load, which is typically at 85 to 90 percent load.

DP is when the propellers (thrusters or main propulsion or both) are used to stay at a given position (+/- a few meters) and heading (to minimize the impact of wind, current and wave action on the vessel hull). It is sometimes used for work orders close to a drillship or when performing operations like loading/unloading close to an installation (eg, a drillship or platform). In severe DP operations — for example, in extreme weather or in critical operations where loss of propulsion power could cause significant damage to the vessel, other installations or personnel — the electrical plant is split into a minimum of two separate sections to achieve a higher level of redundancy in the power system.

By doing so, the vessel can maintain its position even if one side of the power plant fails. However, running in split mode generally does not utilize the full benefits of electric propulsion because total optimization of running engines is not possible. Fuel efficiency has therefore often been sacrificed in favor of safety. With the Onboard DC Grid the split mode operation can run more efficiently as the engine speed can be adjusted and optimized to the required load without the need for changing the number of generators online.

In particular, when considering the DP operation, integration of energy storage to the Onboard DC Grid, will set a new standard for response time of the thrust and station keeping accuracy. The energy storage allows main engines to run with a relatively constant power load by charging and discharging the energy storage device depending on the needed thrust to keep vessels position. Thus, the vessel's ability to keep its position will be less dependent on the engines' response time for load transients. Positioning performance can be improved, and the engines can operate even closer to their optimal load conditions. Also, as the throttling of the engine is more constant, tear and wear of the mechanical actuators could also be reduced.

Yachts

One day, a yacht may be transferred to a new port at its maximum speed to be ready to welcome guests, while next day, it is quietly sailing while there is party on board. Whatever the propulsion need should be, the Onboard DC Grid helps to provide the best efficiency and comfort with a reduced use of valuable space.

Ferries

Some ferries carry trains; others carry cars, trucks or passengers. What is common for almost all ferries is that they operate on scheduled routes between two or more terminals. Most of the terminals are located in densely populated areas and even in the middle of cities. The visibility of these ships and their direct effect to the quality of life for so many people create a strengthened awareness and attention to the environmental emissions by ferry owners and operators.

Certain new technologies, such as liquefied natural gas (LNG) engines are being introduced in ferries, and the Onboard DC Grid is particularly well-suited for integrating the LNG power plant with the propulsion, as it gives the possibility to operate the engines at more stable loads with higher efficiency and less methane slip.

The Onboard DC Grid is easily compatible with energy storage devices such as batteries either as a source of energy that is supplementary to the combustion engines or even as the only source if adequate charging can be supplied at the terminal.

8 New order

ABB will equip a newbuild platform support vessel (PSV), owned by Myklebusthaug and located at the Klevan shipyard in Ulsteinvik, Norway, with a full Onboard DC Grid system, including all power, propulsion and automation systems.

The 93 meters long, 4,800 GT type MT 6015 PSV, a multipurpose oil field supply and construction vessel designed by the Norwegian company Marin Teknikk, is due for delivery in the first quarter of 2013. The vessel has five variable-speed diesel generators, four rated at 2,300 kW and one at 920 kW, two 2,200 kW main propulsion units and three additional thrusters for DP operation.

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Footnotes

- 1 In the event of a fault on a component or subsystem, selectivity means (on a functional level) that only the faulty component or subsystem is affected and taken out of operation.
- 2 The term "hotel load" is used with respect to ships to describe their non-propulsion energy requirements, such as lights, air conditioning, computers, water purifiers, radios, etc..

Further reading

Hansen, J. F., Lindtjorn, J. O., Vanska, K. (October 2011). *Onboard DC Grid for enhanced DP operation in ships*. Paper presented at the Dynamic Positioning Conference, Houston, TX, United States.