
REM FORZA

Onboard DC grid

The newest design for marine power and propulsion systems

JAN-FREDRIK HANSEN, JOHN OLAV LINDTJØRN, TOR ARNE MYKLEBUST, KLAUS VANSKA – **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 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: Personnel and equipment must be protected in case of failures and proper selectivity[1] 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 being how to achieve full selectivity and equip-

Footnote

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.

Title picture

Offshore support vessels, like the MT 6022 design shown here, are prime candidates for the onboard DC grid system.

1a Onboard DC grid

1b Traditional AC grid

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

ment protection in ways similar for 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 → 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 → 2. All generated electric power is fed either directly or via a rectifier into a common DC bus that distributes the electrical energy 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,[2] 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.

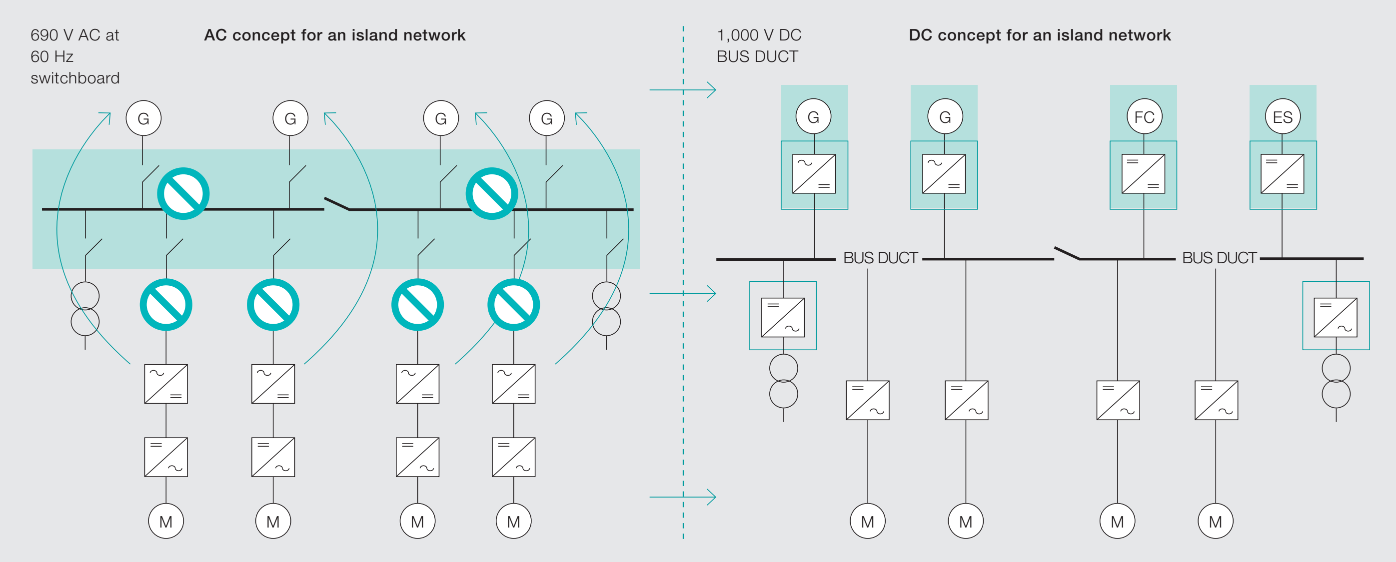
The system has been remodeled in such a way that most of the well-proven products used in today's electric ships such as AC generators, inverter modules, and AC motors can still be used.

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 → 3.

Footnote

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.

2 AC to DC transformation of a generic electric propulsion system



With a distributed approach, the various converters can be placed where it suits the vessel operation or design best → 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 regulation, 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, 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 with 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 from generator fault currents by means of a thyristor rectifier, which also doubles as a protection device for the generator. Isolator switches are installed in each circuit branch in order to automatically isolate faulty sections 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 to 20 ms. This results in a drastic reduction in the DC grid's fault energy levels as compared with traditional AC protection 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 fre-

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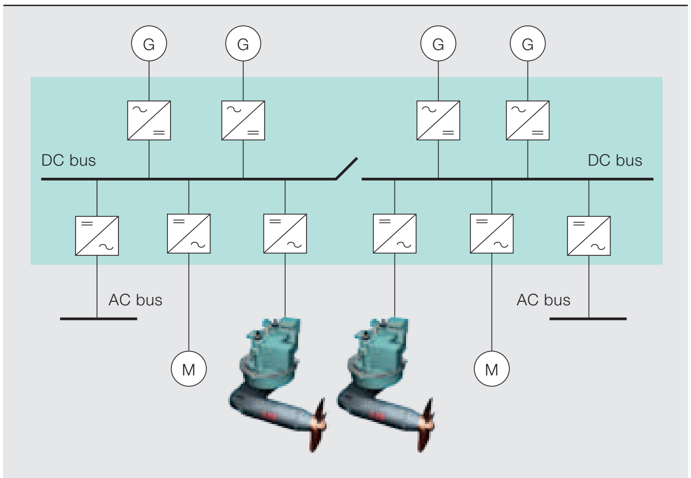
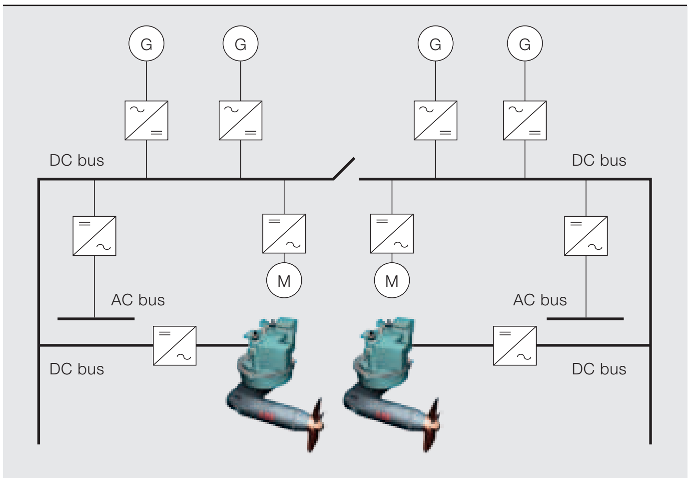
3 Onboard DC grid; multidrive approach



4 Onboard DC grid; distributed approach



The new concept helps solve the traditional fuel efficiency challenge faced in dynamic positioning operation.

quency (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 at 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 50 percent, depending on the engine ➔ 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 ➔ 6.

By eliminating 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 ➔ 7. This creates more space and provides greater flexibility in the positioning of system components in the vessel. In addition, the system enables simpler 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.

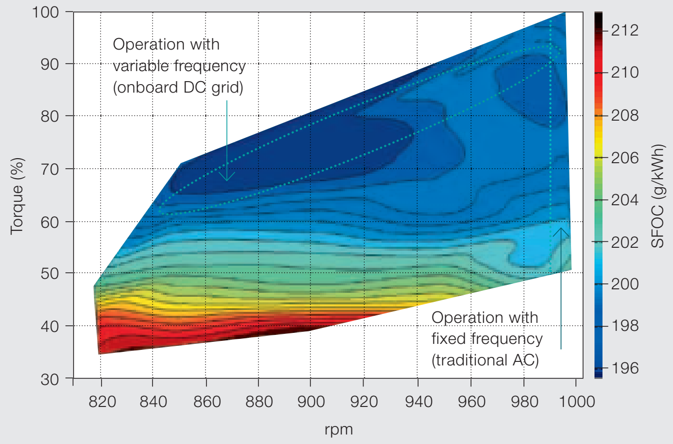
The reduced weight and footprint of the installed electrical equipment will vary depending on the ship type and application. One comparison using a distributed variant of the onboard DC grid system instead of the traditional AC system for a platform supply vessel (PSV), reduced the weight of the electric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

Dynamic positioning vessels

The variable power consumption of anchor handling vessels and other offshore support vessels make them very good candidates for the onboard DC grid system ➔ 8. The new concept helps solve the traditional fuel efficiency challenge faced in dynamic positioning (DP) operation. 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, eg, 85 to 90 percent load.

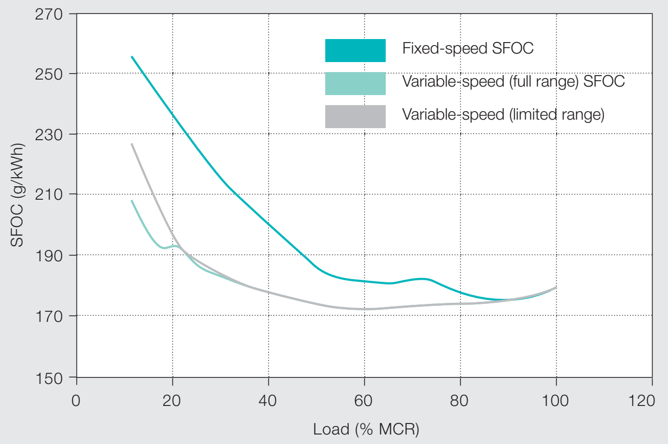
DP is when the propellers (thrusters or main propulsion or both) are used to stay at a given geographical position (+/- a few meters) and heading (to minimize the impact of wind, current and wave action

5 Engine fuel tests at variable speed (specific fuel oil consumption); 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 loading.

6 Engine fuel characteristics at variable speed (specific fuel oil consumption)



Further analysis has been done, in cooperation with an independent engine manufacturer, on a medium-speed engine range typically used in OSV power plants showing a reduction in SFOC of over 20 percent at low loads.

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

8 New order

ABB will equip a “newbuild” platform supply vessel (PSV), owned by Myklebusthaug Management and located at the Klevan shipyard in Ulsteinvik, Norway, with a full onboard DC grid system, including all power, propulsion and automation systems.

The 93m long, 4,800 gt type MT 6015 PSV, a multipurpose oil field supply and construc-tion 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 2,240 kW and one at 920 kW, two 2,200 kW main propulsion units and three additional thrusters for DP operation.

on the vessel hull). This 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.

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Further reading

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