Variable speed power generation in high voltage marine power systems

Dynamic AC

Variable speed power generation can provide significant fuel savings with diesel electric propulsion when the operational profile of the vessel has a high degree of variation in speed and power demand.

The Dynamic AC (DAC) concept by ABB enables optimising the total fuel consumption of the vessel by adjusting the rotational speed of the diesel generating sets and allowing the system frequency to vary within the specified range. Direct current (DC) solutions have also been considered, although the technology is challenging for high voltage power systems.

Fuel savings by variable speed power generation

When operating a vessel requires considerable variation in speed and power, diesel electric propulsion is a natural choice because of flexibility and fuel economy. The ability to freely connect generators online and offline according to power demand enables optimisation of the power plant for several operating points, though there is still ample room for improvement.

Specific fuel oil consumption (SFOC) of combustion engines varies according to load, which can cause significant differences in fuel economy between two operating points. Especially a load step, where a new engine needs to be called in, may increase the specific consumption dramatically. It is possible to overcome this issue by variable speed power generation, when the engine speed and efficiency can be adjusted with the loading.

The fuel saving potential in a vessel is based on operational profiles. Figures [PRSPEED] and [PRPOWER] present exemplary speed and power profiles for a cruise vessel with four generators in the power plant. In this example, variable speed power generation can provide 4 to 6 per cent annual fuel savings in comparison to conventional systems.

Dynamic AC concept

Variable speed power generation has been available from ABB since 2011, when the Onboard DC Grid concept was introduced for low voltage systems. The new Dynamic AC concept, introduced in 2016, is intended for larger vessels that require high voltage power systems.

Dynamic AC is based on variable system frequency in the main power systems. The main engines are running at adjustable speed in the 80 to 100 per cent range, generating electric

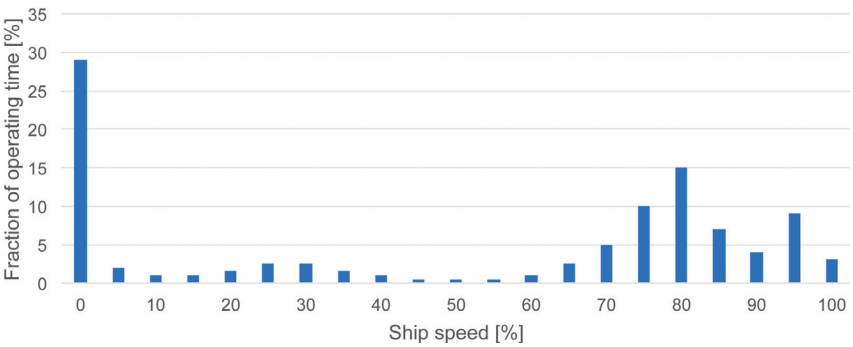

Figure [PRSPEED]: Example of a speed profile for a cruise vessel

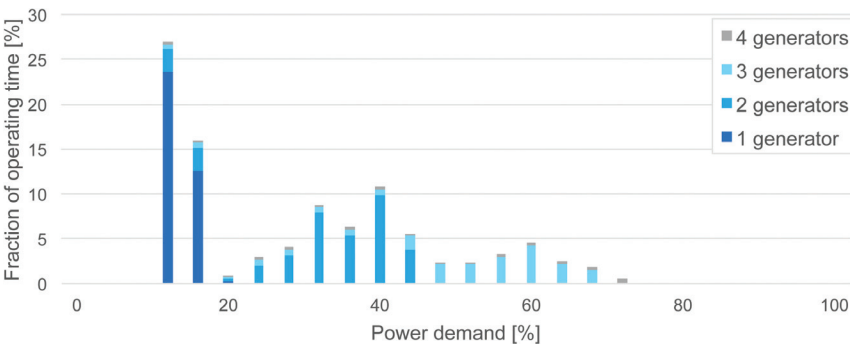

Figure [PRPOWER]: Example of a power profile for a cruise vessel

power with a corresponding frequency. As illustrated in Figure [DAC], the power system layout is similar to a conventional system, with the exception of being designed for variable frequency.

The Dynamic AC concept is based on proven technology, since it utilises only existing products that are dimensioned for variable frequency and integrated to operate together. The user experience is similar to conventional systems, because the control of speed and frequency are automated within the power management system. Any consumers sensitive to frequency are supplied by island converters that are configured to produce constant voltage at 50 or 60 Hz frequency.

Minimising power conversions

A key factor in optimising the investment cost and footprint of the system is the on board power distribution. There are numerous consumers on board that are supplied by power electronics and hence are insensitive to supply frequency. In some vessels, the auxiliary and hotel loads can be in the range of megawatts and have strict requirements for redundancy. It is therefore necessary to critically review all requirements and seek opportunities to minimise unnecessary power conversions.

The principle of optimising the on board power conversions is illustrated in Figure [CONV]. Instead of converting all electric power for auxiliaries and other consumers into constant frequency, it may be beneficial to supply the fire zone substations at variable frequency and utilise distributed island converters for selected consumers.

Most auxiliary equipment comprises motor drives supplied by frequency converters. These drives can be supplied directly from the variable frequency system, as well as most electronic devices and LED lighting power supplies. With careful analysis and purpose-driven design, it is possible to suppress the installed power of island converters into a fraction of the original plan.

Direct current technology

Onboard DC distribution provides several advantages over traditional AC systems, such as a more compact

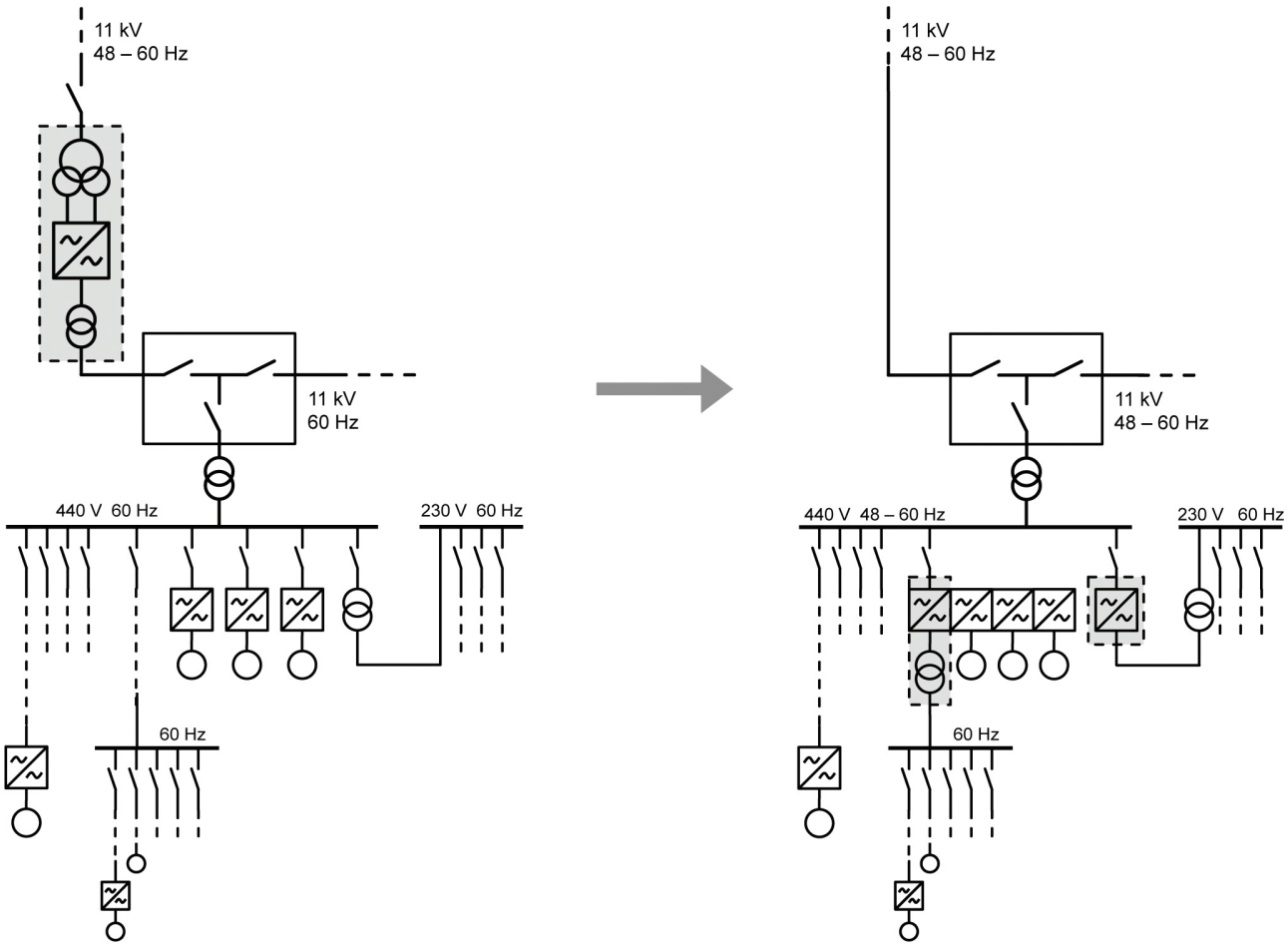

Figure [CONV]: Centralized power conversion replaced by distributed island converters

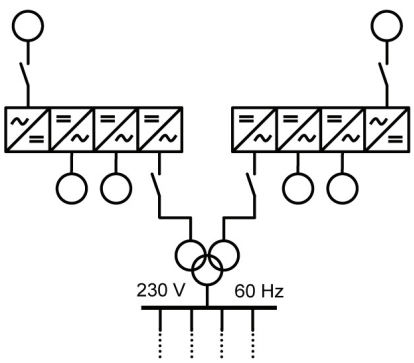

Figure [ALT]: An alternative configuration for variable speed power generation

footprint and flexible integration of energy storage and alternative power sources. However, technology for high voltage DC systems still requires development to cover all requirements on safety and reliability.

Figure [ALT] presents a principle of a compact high voltage system based on DC technology. While all consumers are supplied by power converters, either motor drives or island converters, it is possible to omit the main switchboard and connect the generators directly into the power converters. The DC capacitors of the multidrive converters may need to be detached from each other because of redundancy and reliability, but the power flow between converter lineups and power boards can be managed with the help of the three-winding transformers.

The way forward

There are naturally numerous variants available depending on the vessel type and purpose, as the solutions presented describe only the basic principles. Finding the optimum for each project requires careful analysis of different alternatives and an innovative attitude towards new solutions.

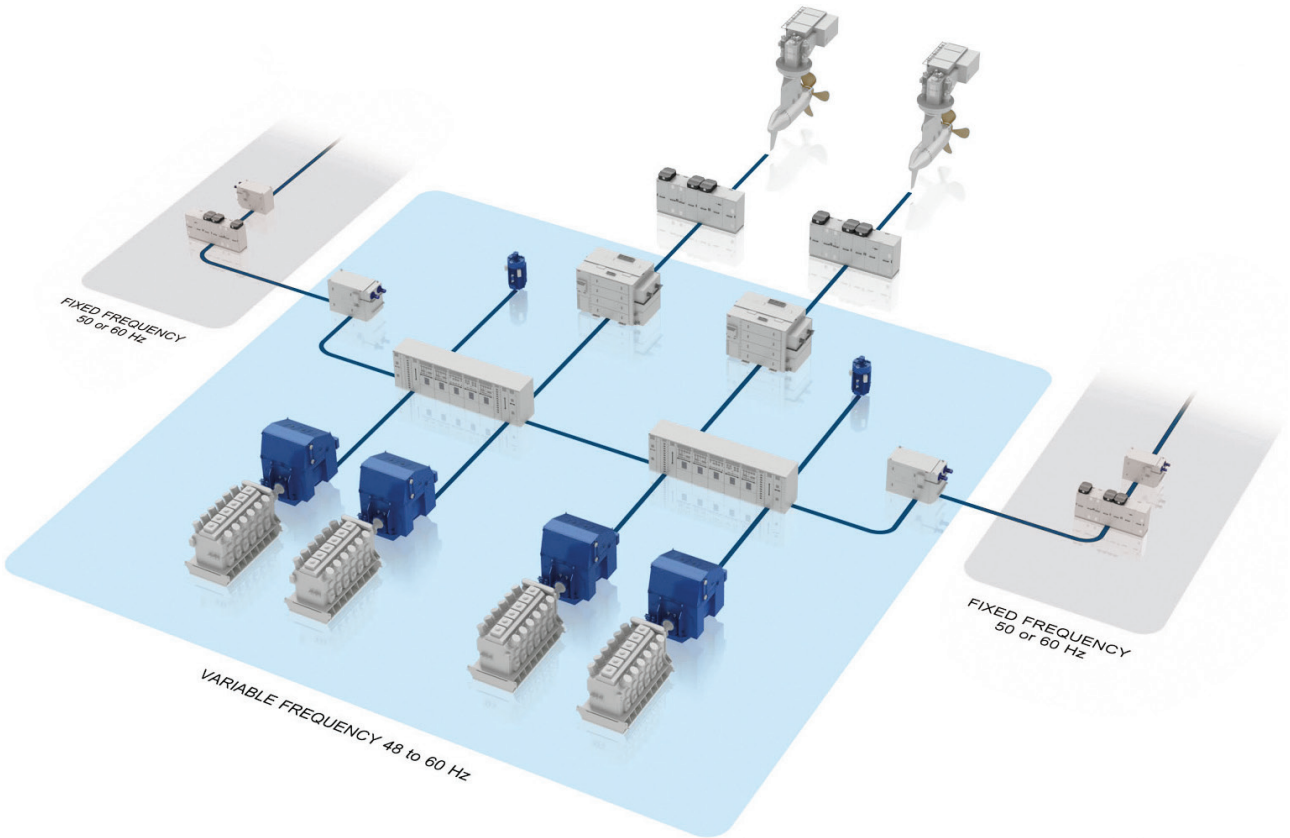

Figure [DAC]: Layout of the Dynamic AC concept

Energy efficiency is a sustaining trend, which still has much unexplored potential. On board power generation with variable speed engines is a major step forward, and is now available for the higher power range as well.

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