Marine power systems

The use of power stacks in marine electric system construction can answer the demand for complex electrical architectures

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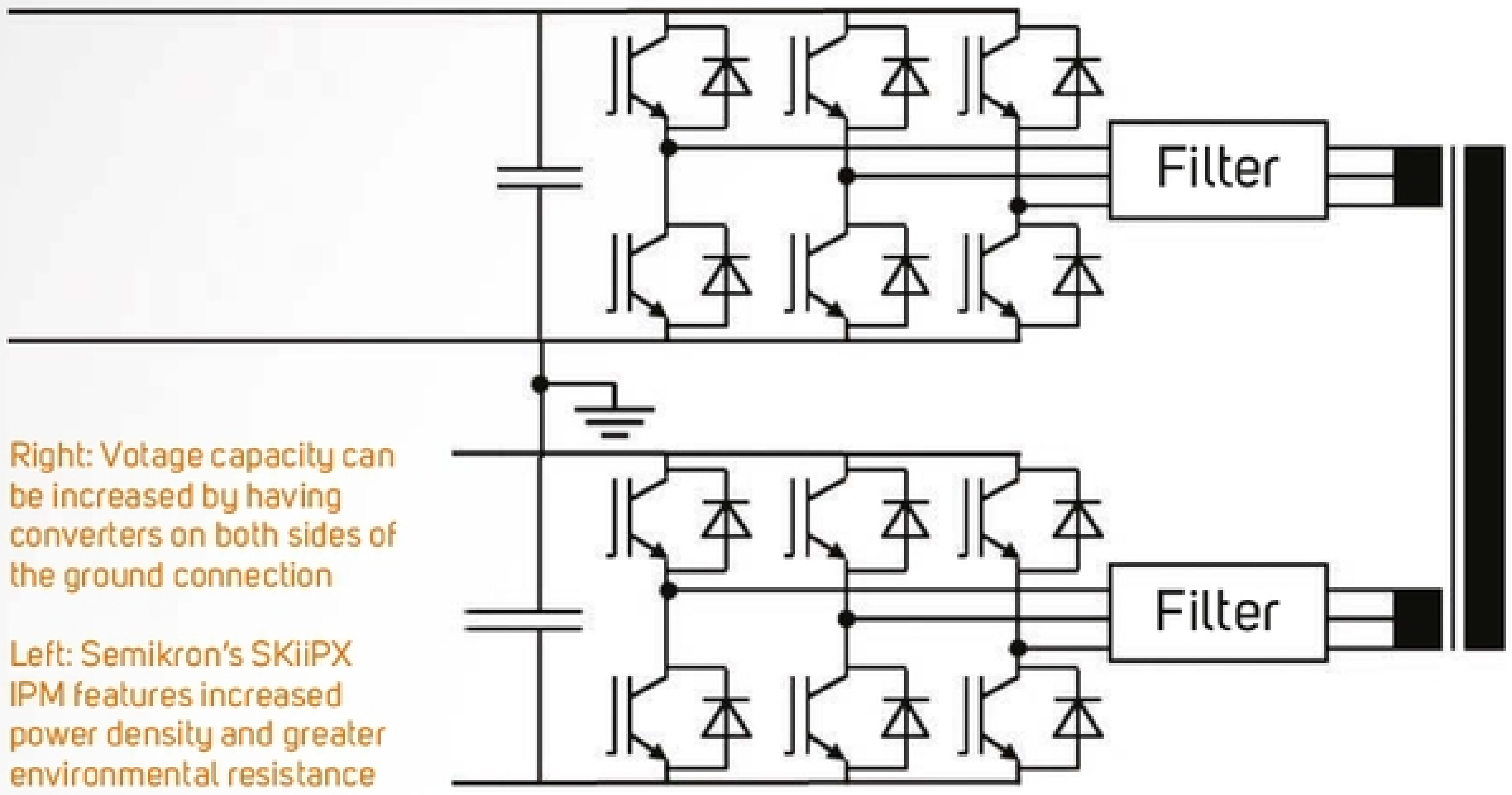
As in many other fields, marine applications have to cope with environmental regulations. Power electronics is a key technology in optimizing energy management, providing the conversion needed to operate motors, generators, battery storage and shore supply. Complex power electronics systems are represented as the interconnection of conversion blocks, as in AC/DC, DC/AC, DC/DC and AC/AC. This gives a good overview on a system level, but hides a lot of technical problems that converter designers have to handle. Converter design is still restricted to specialists; nevertheless, the advent of stacks is a step toward simpler system construction. The emergence of complex electrical architectures in marine applications will increase the need for power converters with high reliability and simple maintenance requirements.

From device to converter

Building a power converter has always been a compromise between the available power semiconductor switches, converter topology and system requirements. Often several technical solutions achieve a project's goals, especially when dealing with high-power converters.

Power semiconductor manufacturers are in search of the perfect switch – one with high voltage and current capability, as well as low losses. This search is informed by semiconductor material and process improvement (silicon-based thyristor, GTO, MOSFET, IGBT, IGCT), and also by converter topologies that use multiple cells or switches. The implementation of power devices in a converter has become more complex, as system requirements grow increasingly stringent regarding lifetime, reliability, EMI and cost. The emergence of new materials (such as silicon carbide) will certainly have an effect on the design of converters and power systems.



Right: Votage capacity can be increased by having converters on both sides of the ground connection

Left: Semikron's SKiiPX IPM features increased power density and greater environmental resistance

Nevertheless the basics of power electronics will endure and a new trade-off will be found.

IGBTs are currently well established in industrial applications. A product range of 600-6,500V covers low-voltage as well as medium-voltage applications. After its success in industrial motor drives with 1,200V technology, the wind industry encouraged a push on the 1,700V class, improving chip performance in terms of robustness and loss reduction.

Using stacks

The basic building block of converters is the half bridge. This may be either a power module (transistor and diode) or an intelligent power module (IPM), which includes driver, sensor and protection functions integrated into a single device. The SKiiP IPM from Semikron also includes its own cooling system. The complete power device is designed and optimized to achieve a high level of cycling capability (meaning it has a long life), and outstanding reliability. The integrated drivers ensure close protection by the integrated sensors, adding reliability at system level. The insulation is designed and tested to exceed industrial isolation requirements.

SKiiP devices use the latest IGBT chip technology plus other state-of-the-art techniques – such as using sinter technology instead of solder, and spring contact instead of solder contact – providing incomparable cycling capability. The driver uses a digital-based signal transmission for logic signals, and also for current, voltage and temperature measurement, thus ensuring safe electrical insulation in accordance with standards. Built-in thermal sensors close to the chip, and fast current sensors, ensure safe operation up to hard short-circuit. In addition, a CAN interface is available for application settings and for detailed diagnostics in fault conditions.

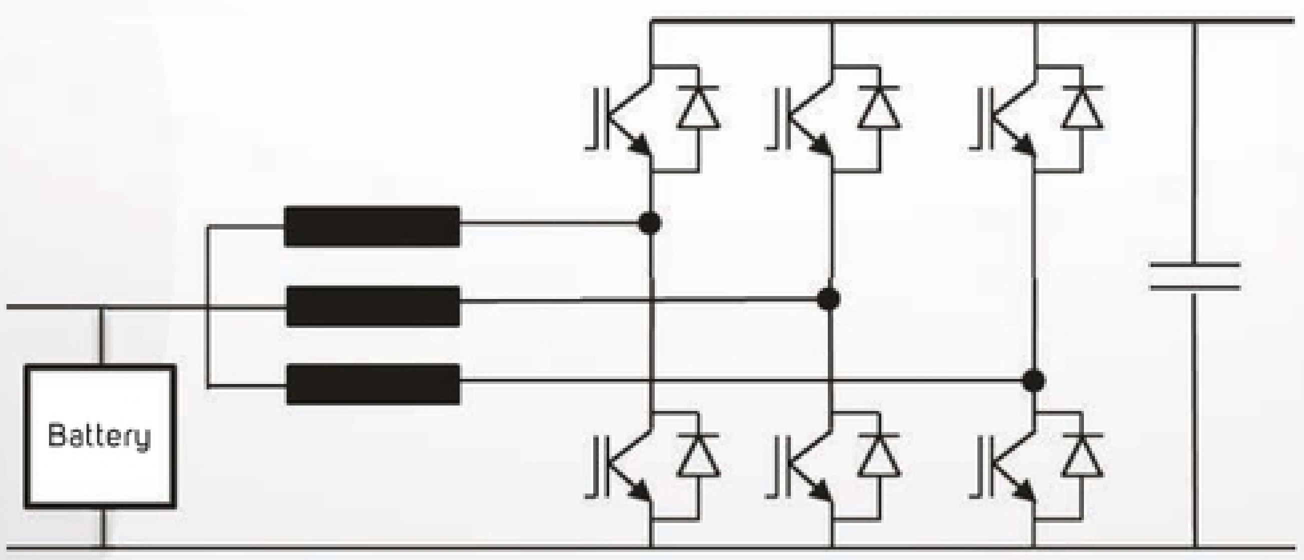
Using this IPM, Semikron offers a range of three-phase inverters – the so-called stacks – with water-cooled designs, qualified and ready to use in a power cabinet.

The design meets a very wide range of international standards, from motor drives to solar applications, and has passed a stringent environmental qualification including mechanical, climatic, biological, test-in-transport and operation.

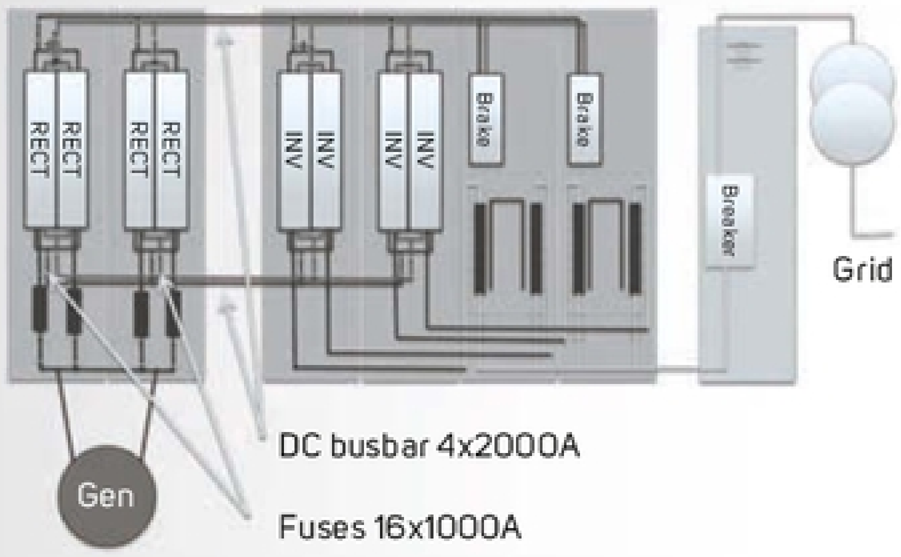
The stack product range offers standard frame sizes and various electrical characteristics, and covers a wide range of applications. The DC link, using dedicated qualified film capacitors, reaches 100kHrs life under nominal conditions. Additionally, the SKiiP built-in sensors provide the highly accurate current and voltage measurements required by the application control.

Semikron's 690V AC inverter block, Semistack RE, ranges from 1MVA to 1.5MVA. With output current up to 1,400A and DC link operation of 1,250V, it includes all the power parts required in a three-phase voltage source inverter and interfaces to ease cabinet integration: AC and DC power connections, control interface, water coupler and mechanical fasteners. With more than 60 years of experience in power semiconductors, and 30 years in stack development, Semikron is able to provide fully specified functions, extensive testing, and UL certifications.

An example of two stacks integrated into a 600 x 600 x 2,200mm cabinet, with water-cooled du/dt filter is shown on page 87. A control board is needed to change this stack into a converter with dedicated characteristics, by providing high-side and low-side logic signals to the IGBT switches, and monitoring current, voltage and temperature feedback from each half bridge, as well as error signals. Both converters are internally connected on the DC side. To ensure good coupling between the two DC links, a bipolar connection (using busbar construction) is implemented on the top and bottom of the stack.



Right: A three-phase inverter connects DC to AC, but may be used as a three-phase interleaved buck-boost converter



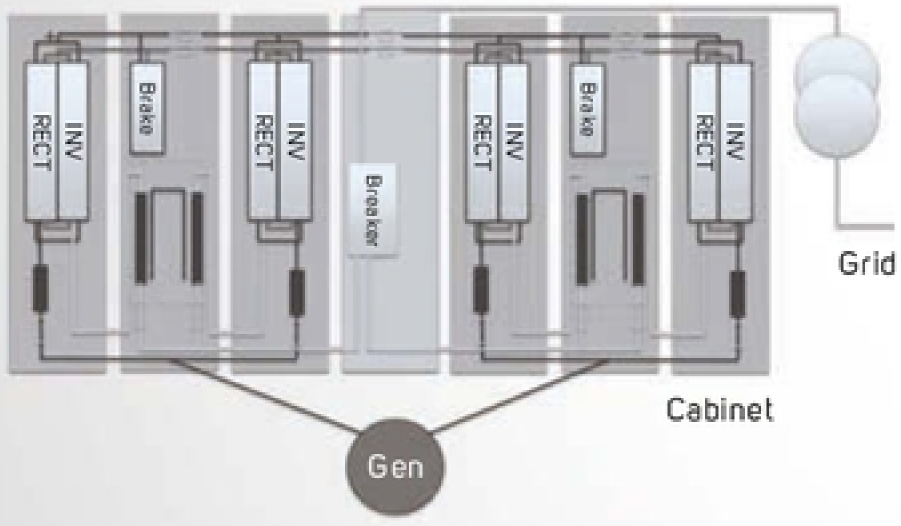


Figure 1 (top): An parallel AC/AC converter with a range of 4-5MW

Figure 2: A similar system, but using an alternative wiring configuration

AC/DC, DC/AC and AC/AC stack combinations

Using such three-phase stacks makes it possible to increase power by block parallelization. Inverter parallelization requires special care. Additional inductors are needed between inverter outputs to ensure good dynamic current sharing. This hard-paralleling mode is made easier by the use of a parallel board, which provides an interface between the inverter blocks and control board by collecting logic signals and scaling sensor signals. The use of a multiple winding generator or motor offers a way to get rid of additional parallel inductors. With the complexity of multiple control boards, active paralleling is also possible. Many factors have to be considered in such a multiconverter system – the control architecture is a key point, as it may include separate inverter control (for redundancy purposes, for example).

Converters used in wind applications feature two three-phase inverters back-to-back, one connected to the grid and the other to the generator (AC/DC and DC/AC). The evolution of generators, caused by power increase and maintenance-cost-reduction targets, is moving from double-fed induction generators (DFIG) to permanent magnet (PM) generators. Even if this move does not change the topology used, it has modified the sizing conditions and the overall power of the converter (increasing from about one-third of the installation power for DFIGs, to full power for PM generators). Together with increases in windmill power (up to a total output of 10MW), the need for high-power converters is continually growing.

The following example shows how an AC/AC converter with a range of 4-5MW may be designed using stacks in parallel, and how the wiring of these blocks is affected. In the first configuration (shown in Figure 1, above), the rectifier function is built out of rectifier stacks (RECT) in parallel, and the same for the inverter (INV). Each cabinet contains two stacks. It should be noted that the inverter and the rectifier use the same stack. Filtering is accomplished by line filtering on the grid side and du/dt filtering on the motor side. The line filter uses separate filters per converter for current sharing. Additional brake choppers are part of the system. The result shows a good separation of functions – rectifier, inverter and filter. This functional separation creates a significant DC connection between rectifier and inverter, handling the whole DC current, and DC fuses sized to carry the DC nominal current of each converter. The second configuration (Figure 2), shows a similar AC/AC converter with the same stacks, power, filters and cabinet, but wired differently. Each cabinet is made out of one rectifier and one inverter back-to-back. Cabinets are parallelized using individual filters that improve current sharing. This configuration reduces the need for high-current DC distribution and corresponding high-current fuses. The energy goes directly from AC to AC through each paralleled block. DC fuses handle only unbalanced current between cabinets and have to be sized for transient operation (brake chopper operation if needed). The DC connection between cabinets is necessary to ensure a common DC voltage for control purposes, in case of hard paralleling.

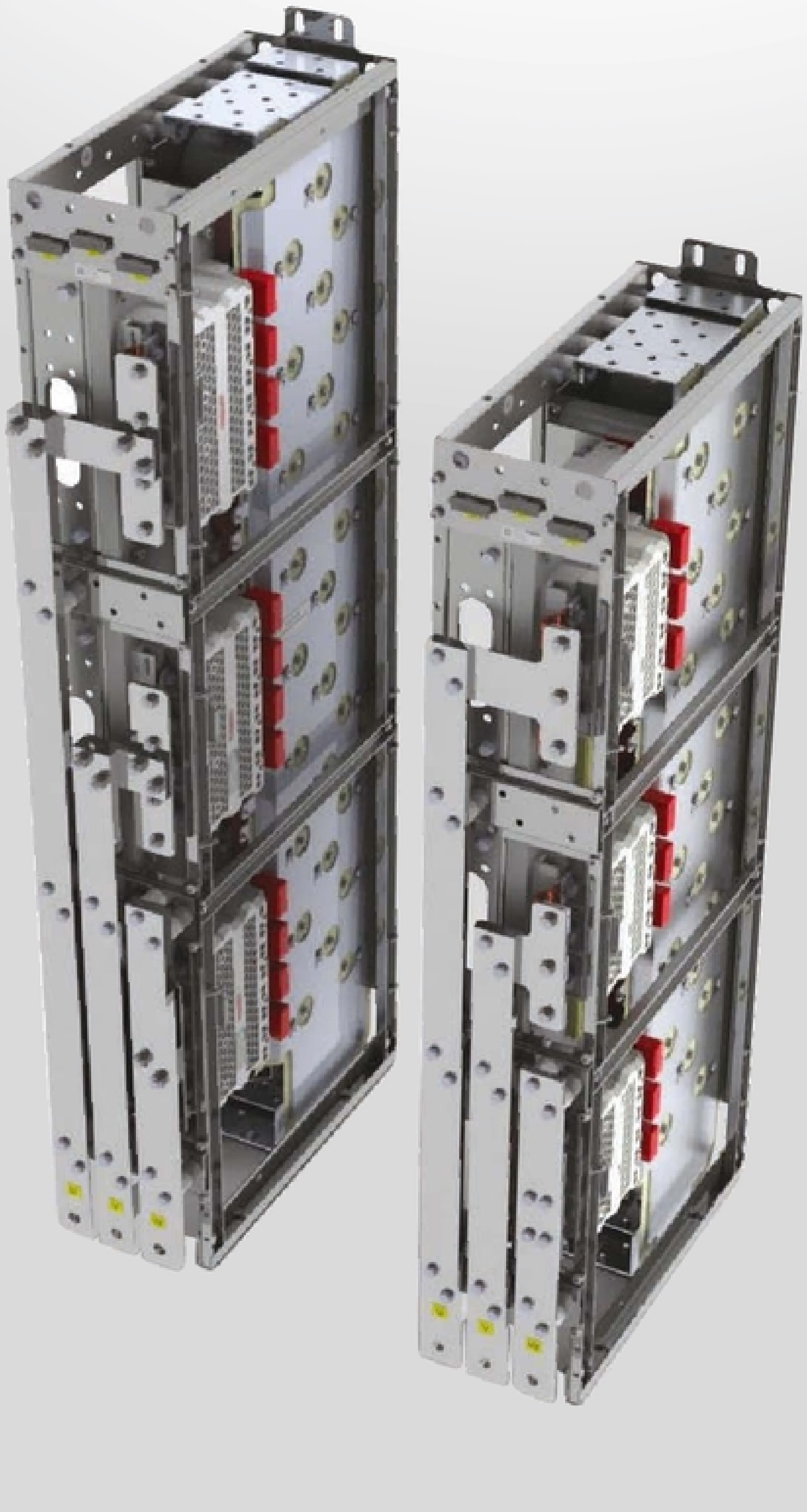
DC/DC combinations

A three-phase inverter converts DC to AC, but may be used as a three-phase interleaved buck-boost converter that will be able, as a reversible converter, to charge and discharge batteries, with the benefit of filtering optimization due to interleaving. By using interleaved switching on a three-phase configuration, the apparent switching frequency seen from the DC side (input or output) is three times the switching frequency, therefore reducing the filter size. Inductor optimization is also improved by splitting current over smaller-sized inductors. The ripple current in the battery can be further improved by additional LC filtering, if required. From a system point of view it reduces the number of converter blocks, thus improving standardization.

Increased operating voltage

When fewer megawatts are considered, system optimization tends to increase operating voltage (from low to medium voltage) in order to reduce wire gauge and corresponding losses. If the benefit for cabling is straightforward, this brings a number of issues regarding converter design, performance, cooling and maintenance. Though multicell converters are now widely used in many applications, there are alternative solutions in cases where the conditions do not lead to a clear choice.

Stack paralleling allows current increase. Stack series connection is also a possible solution to increase voltage capability. The main issue lies in isolation. One well-known method for increasing voltage capability is to have converters on both sides of the ground connection (positive and negative). The outputs of each stack cannot be directly connected and the use of a multiple winding transformer or motor is required. Once again, the interaction between system and component is a key point. The choice between a dedicated high-voltage converter using a low switching frequency, and widespread industrial component technology, is less a technical decision than an industrial one.



Right: An example of two stacks integrated into a 600 x 600 x 2,200mm cabinet, equipped with water-cooled du/dt filter

Below left: Semikron's range of three-phase inverters are water-cooled, qualified and ready for use inside a power cabinet

Stack benefits

Using limited numbers of subassemblies and taking advantage of standardized production and cost reduces the maintenance requirements of stacks. A new generation of power semiconductor chip technology is introduced every three to five years, and is obsolete after 10-15 years. Upgrading converters due to component obsolescence is not that simple even if, from a performance perspective, new chip generations always provide improvements. The backward compatibility has to deal with mechanical, thermal and electrical parameters, but also with system-sensitive matters such as EMI. The IPM includes drivers as well as current, voltage and temperature sensors. Electronic circuit life of each circuit is covered by the IPM itself.

Semikron is already working on the next generation of power stacks. Using its newly developed SKiiPX IPM, power density will be increased, as will the ability to withstand environmental factors.

New SKiN technology, together with efficient water cooling, provides outstanding performance. The modular construction of the SKiiPX offers modularity regarding current rating. The housing provides a 3K4 climatic category together with a pollution degree 3 rating, improving operation in harsh environments. Combined with innovative construction and optimal thermal management, it will lead to a 3MW, four-quadrant converter, fitting into an 800 x 600 x 2,000mm cabinet.

For a converter manufacturer, purchasing a higher-level function such as a stack strongly reduces the required development and manufacturing effort, improves time-to-market and quality yield, and eases lifetime management. For a system integrator, the stack represents a way to build an innovative power system, using a simple and reliable power function, without the constraints of power device implementation, freeing up development resources.