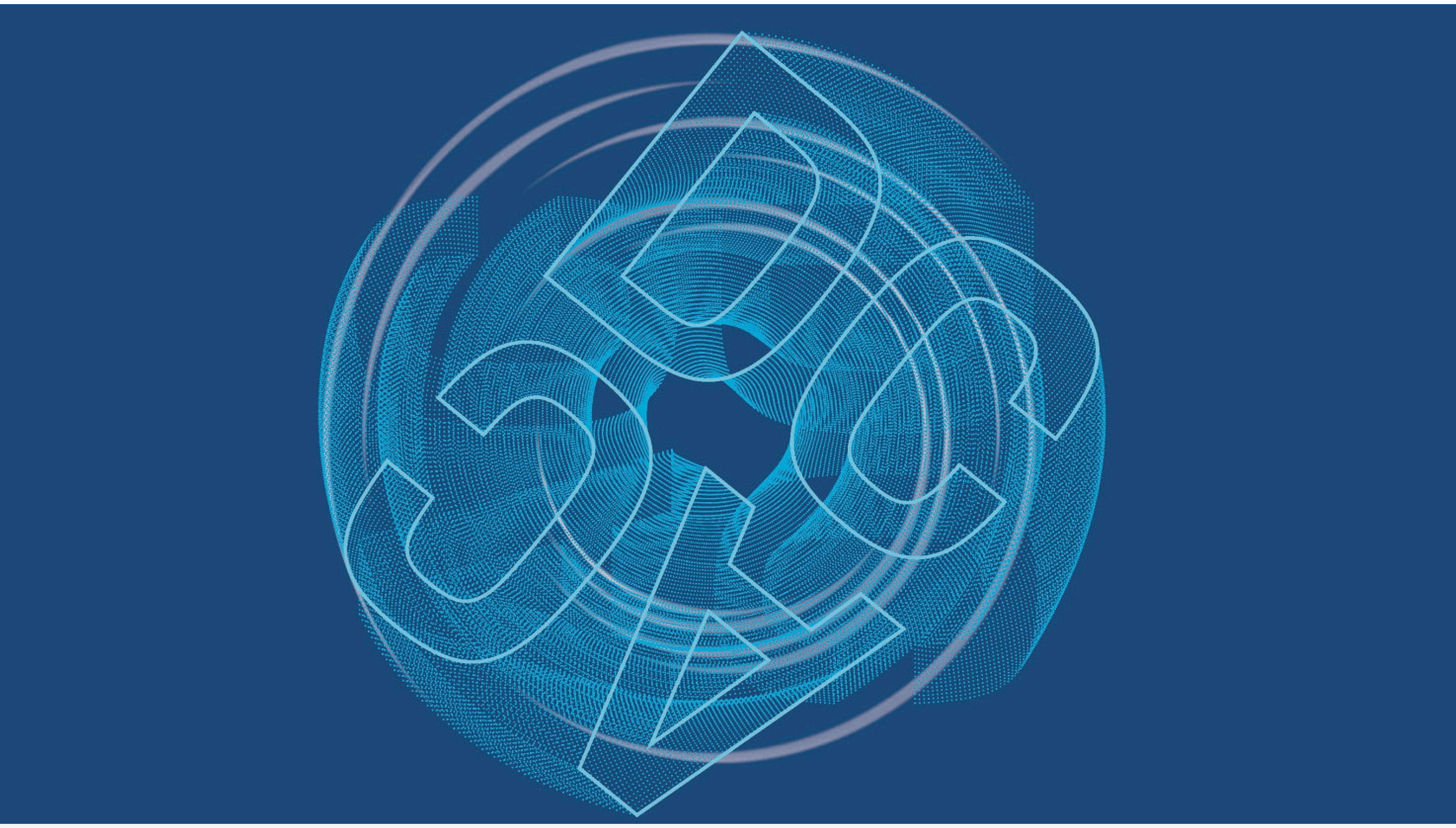

Modular multi-level inverter: Turning DC into AC

19/03/2025 Porsche Engineering has developed the concept of an 'AC battery' for electric vehicles that unites numerous components in a single part. It is controlled by a standardized control unit concept with a particularly powerful and real-time-capable computing platform. The system was developed as part of a feasibility study, tested on the test bench, and demonstrated in a vehicle.

The drive system in electric vehicles usually consists of separate components: A high-voltage battery with battery management system, power electronics for controlling the electric motor, and an on-board charger for charging with AC power. The power electronics convert the DC voltage of the high-voltage battery into the sinusoidal three-phase AC voltage for the traction motor using a pulse inverter.

This structure has proved its usefulness in current vehicles, but could be further improved in the future. "The trend in the automotive industry is toward highly integrated components," says Thomas Wenka, Specialist Project Manager at Porsche Engineering. "This opens up new possibilities in terms of housing size, weight and cost reduction, reliability and efficiency." The development team at Porsche Engineering used the high integration level of components to develop an AC battery system as part of a feasibility study. It integrates the normally separate functions of the battery management system, pulse inverter, low-voltage DCDC, and on-board charger into one single component.

For the study, the developers at Porsche Engineering have divided the high-voltage battery of the electric drive into 18 individual battery modules, distributed over three phases. They can be controlled individually by power semiconductor switches. The flexible interconnection of the individual battery modules into a Modular Multilevel Series Parallel Converter (MMSPC) as a distributed real-time system enables dynamic modeling of the voltage curve, so that the sinusoidal three-phase AC voltage for the motor can be generated directly from the DC voltage from the battery modules. “With the MMSPC, both the direct control of the electric drive motor while driving and the direct connection to the AC grid for charging the battery is possible,” explains Daniel Simon, Specialist Project Manager at Porsche Engineering.

Numerous technical advantages

Other advantages include easier scalability to various drivetrain variants as well as safer handling of current- carrying components during servicing or in the event of an accident. “Then the MMSPC is switched off and the system effectively reverts back to its individual modules, meaning that only the module voltage can still be measured,” says Wenka. In addition, failure protection increases in the event of a possible defect in individual battery cells, as the intelligent control system bypasses the affected battery module. This makes it possible to implement a so-called limp-home function to the nearest workshop with reduced power. With a conventional battery, this would cause a vehicle breakdown. The concept of the AC battery also offers the technical potential for a fast charging capability capacity through pulsed charging.

A major challenge in implementing the AC battery concept was the development of a powerful and fast central control unit that can precisely control the individual battery modules. “Dynamic reconfiguration of the battery modules in sine wave modeling is made possible by the underlying distributed system, which must meet real-time requirements under all circumstances,” says Simon. “After all, a delay in switching the modules would lead to defects in the battery packs and the associated power electronics.”

Real-time capable computing platform

In parallel with the concept of the AC battery, the electronics experts at Porsche Engineering have developed a control unit with a particularly powerful real-time, uniform, and highly integrated computing platform. The individual functions of the AC battery, such as motor and battery management, as well as the charging function, run on it in parallel. The control unit platform consists of two elements, a project-specific so-called baseboard and a project-independent computing unit in the form of a system-on-module with a uniform interface to the baseboard. “The processing unit represents a heterogeneous multiprocessor platform and runs as a single system-on-chip. It combines a field-programmable gate array (FPGA)—an integrated circuit with programmable hardware— for data control and monitoring with regard to the real-time capability of the system, and a powerful multicore processor for processing large amounts of data in a single component," explains Simon.

"The FPGA can take over complex calculations to relieve the processor and supplement missing peripherals, which are significant advantages in terms of scalability and flexibility compared to the usual pure microcontroller solutions. And by selecting the derivative within the system-on-chip family, the performance can be scaled from basic ECU requirements—such as I/O-driven, communication gateway or power electronics—to complex ADAS systems with additional GPU and video codec requirements." One special feature of the approach is the software- focused implementation of the control unit functions. "One part runs on a processor, which uses the FPGA for fast control and the optimal switching strategy, and ultimately controls all modules synchronously. This enables dynamic reconfiguration through software. However for that to work, the power electronics on the modules have to implement this switching strategy," says Simon. "By using a systemon- chip approach with a CPU and FPGA, we enable hard real-time capability that cannot be achieved with normal microcontrollers."

Together with the new control unit platform, Porsche Engineering has implemented the concept of the AC battery in various prototypes and successfully tested it on the test bench. The system was also integrated into a test vehicle to demonstrate its basic functionality. "The development of the new control unit platform was absolutely necessary for the AC battery. However, since it can be flexibly adapted, it has become a separate project that will be continued," says Wenka. For new projects, the system-on-module and some of the associated software can be reused, and the functionality of the baseboard can be easily upgraded to include the required hardware functions and interfaces.

The control unit can therefore be flexibly adapted to new requirements and is therefore suitable for all applications where high computing power and real-time capability are required, and the requirements can still change during the ongoing project. "This allows the project-independent combination of a system-on-chip on the system-on-module of the control unit to also handle other complex tasks well, which makes it a good choice as a functional prototype platform for prototype development," explains Simon. Advantages over conventional prototype ECUs include faster function development, to name one example: The hardware provides high computing reserves, and the basic software and existing software blocks can be used as a very good starting point in the development of a control unit. "There are currently plans to initially use the new control unit platform for prototype development at Porsche Engineering," as Wenka reports. "In principle, the concept is however also suitable for series applications with minor modifications."

Info

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