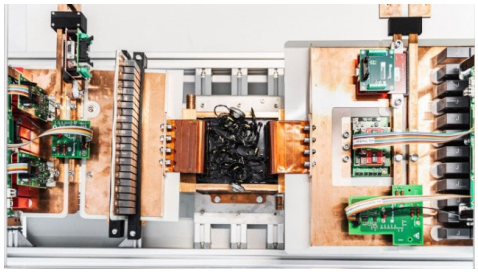
Press Information

DC-DC converter based on silicon carbide semiconductors achieves high efficiency for use in electrical agricultural and construction machinery

November 15, 2023

The electrification of agricultural and construction machinery currently powered by combustion engines is an essential contribution to reducing emissions. The progressive expansion of renewable energy sources means that climate-damaging emissions can be completely avoided in the future. The aim of the MUSiCel research project is therefore to research and test innovative components and methods for an efficient, locally emission-free energy supply for agricultural and construction machinery. At the heart of the supply system is a mobile and compact high-performance DC-DC converter that is integrated into the vehicle.



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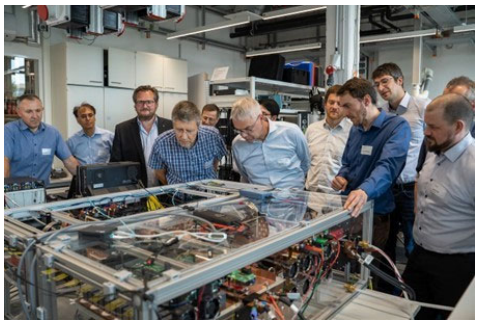
250 kW 50 kHz DC-DC converter developed as part of the project.



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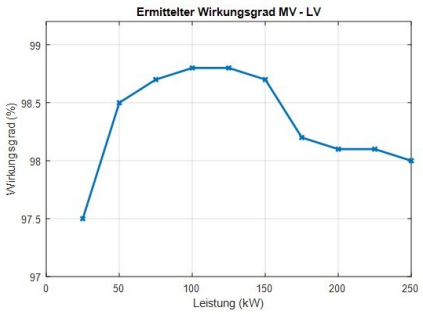
A galvanically isolating voltage converter was realized as part of the MUSiCel project. The project partners involved include Infineon Technologies AG, STS Spezial-Transformatoren-Stockach GmbH & Co. KG, the Institute for Drive Systems and Power Electronics at the University of Hanover and the Fraunhofer Institute for Energy Economics and Energy System Technology IEE. The project was funded by the Federal Ministry of Economics and Climate Protection (BMWK) and supervised by the Project Management Jülich (PtJ).

By using innovative silicon carbide (SiC) wide-band-gap semiconductors, a unique combination of an output power of 250 kW and a switching frequency of 50 kHz was achieved. The efficiency across the entire power range exceeds 98 %. At 100 kW, an efficiency of even 98.8% was measured. The converter developed has the status of an early prototype. The project results show that by using SiC power semiconductors, a DC-DC converter with high power and high switching frequency with very good efficiency can be realized.

"Regarding the further development of the voltage converter, an interconnection of four converter stages in a so-called ISOP configuration would be conceivable. This would increase the MV voltage to up to 8 kV," says project manager Anton Gorodnichev, Fraunhofer IEE. "Such further development could take place as a follow-up project. For example, it would be interesting to optimize the installation space and power density."

Another special feature of the project is the use of 3.3 kV SiC MOSFET modules, which were first developed and optimized by Infineon. The successful use of

Presentation of the developed demonstrator at an information event.



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Measured efficiency of the 250 kW 50 kHz DC-DC converter.

these modules in the MUSiCel DC-DC converter confirmed the suitability of the modules for an application with high power and voltage. These innovative modules were presented to the public at the PCIM 2023 trade fair. Compared to IGBTs, the SiC modules have a lower on-state resistance and significantly shorter switch-on and switch-off times. As a result, semiconductor losses can be reduced in both nominal and partial load operation. In addition to agricultural and construction machinery, these power semiconductors can be used within the powertrains of trams and trains. Modern medium-voltage solid-state transformers can also be further optimized in terms of efficiency by using SiC MOSFET modules.

The combination of high power and high switching frequency is of great importance for mobile applications. The size of the inductive and capacitive components can only be significantly reduced with a high switching frequency. However, this leads to high losses in the converter, as each switching operation generates energy losses in the circuit-breakers. By using SiC-based power switches, a resonant topology and optimized control of the converter, these losses could be significantly reduced. The resonant topology uses a series-resonant intermediate circuit to generate an almost sinusoidal current in the transformer. This means that the otherwise lossy switching processes can take place at zero current and are therefore virtually loss-free.

The DC-DC converter has an input voltage of 2 kV. By connecting four identical converters in series, a system with an input voltage of up to 8 kV could be realized. This enables the low-loss supply of an agricultural or construction machine via a DC cable several kilometres in length. The output voltage is 700 V, enabling the operation of drive solutions on board agricultural and construction machinery.

Project partner, STS, has developed a liquid-cooled high-power transformer and designed it for an operating frequency of 50 kHz and 250 kW. The transformer achieves an efficiency of over 99% and meets strict insulation requirements. In addition, another transformer of an alternative design with a 3D-printed casing was developed by the University of Hanover.

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