Energy
National Research Programmes 70 and 71

Project

Demonstrator of SiC solid-state transformer

Use electrical energy more efficiently with new solid-state transformers

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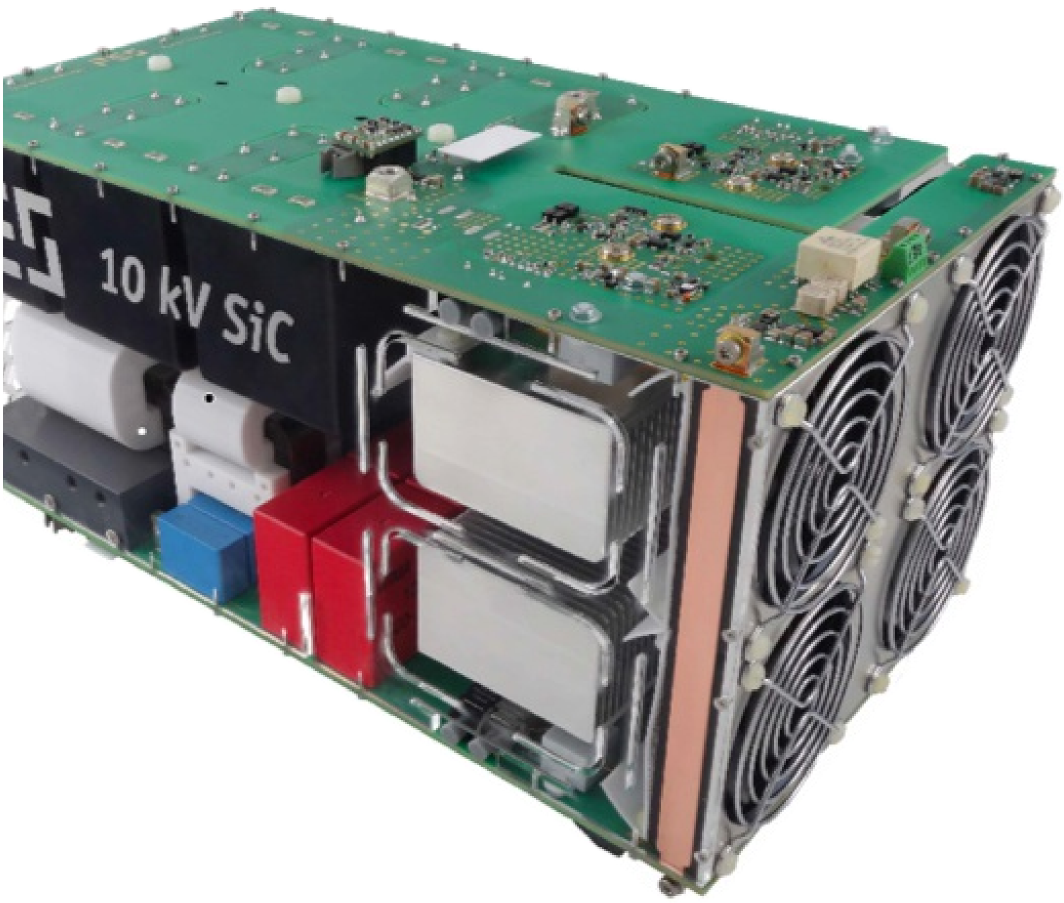
New developments in transformer technology make it possible to optimise the energy supply with intelligent solutions. Researchers at ETH Zurich have developed a super-compact and highly efficient 7kV-400V voltage converter that demonstrates the potential of the new power electronic transformers.



With its compact and efficient design, a solid-state power electronic transformer developed at ETH Zurich gives a taster of the future of electrical energy supply. *Source:* ETHZ

At a glance

- Power electronic transformers allow for the more direct and efficient supplying of energy-intensive systems.
- Researchers at ETH Zurich have developed a new power electronic transformer for the energy supply of computer centres.
- The ETH transformer is only half the size of comparable devices and transmits power with a record efficiency of 98.1 %.

Against the background of climate protection, electricity is becoming increasingly significant. This is because the carbon-free energy carrier produced from renewable sources is predestined for an energy supply without CO2 emissions. On the one hand, the increased use of clean energies such as wind and solar energy is creating numerous new energy producers. On the other, electricity is also used for ever more energy-intensive applications, such as charging stations for electric cars and the operation of computer centres. The efficient transmission of electrical power as well as the frequency conversion and adaptation of electrical voltage will thus become more important in future.

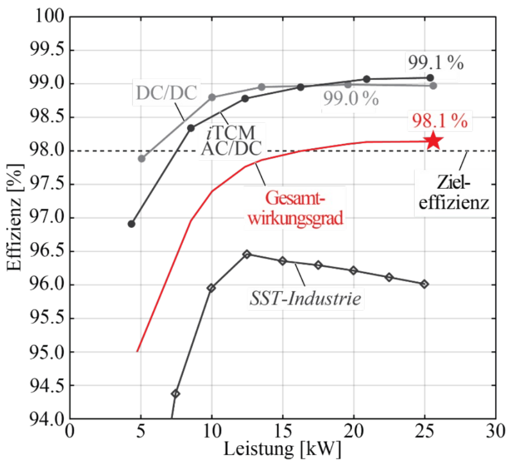
Shorter distances save energy

With many types of electrical energy use, the first step is to convert the alternating voltage available from the low-voltage grid and the socket (230 or 400 volts) into a direct current voltage required by the end device. Because a small part of the energy is lost as heat here, it would make sense for larger systems to draw power directly from the medium-voltage grid. This is the next higher grid level, which is responsible for the coarse distribution of the electrical power and works with alternating voltages of many kilovolts. If the alternating voltage of the medium-voltage grid is converted directly into a direct voltage adapted to the end device, one conversion step could be skipped and the associated energy loss saved. Researchers at ETH Zurich have implemented this concept with the help of a new semiconductor technology – recently developed “solid-state transformers” (SST) with power electronic converter stages based on silicon carbide with which voltage and frequency can be arbitrarily changed and protective functions can be implemented.

The researchers based their work on the case of data centre – a type of large consumer experiencing strong growth. They developed a solid-state transformer that can supply a single server cabinet with 25 kilowatts of power and convert an alternating voltage of 3.8 kilovolts into a direct voltage of 400 volts. This takes place in two stages, the first stage producing a constant direct current voltage of 7 kilovolts and the second stage transforming the voltage down to 400 volts at medium frequency using an isolated circuit.

Reduced to maximum

The device developed by the ETH researchers eclipses existing solutions many times over: due to its high clock frequency, it is extremely compact and thus achieves a power density twice as high as that of devices developed within the framework of industrial research projects. In addition, the efficiency of the voltage conversion is massively increased by the so-called soft switching of the power semiconductors. Appropriate control ensures that there is no voltage across the transistors at the switch-on times and that only a relatively slow voltage build-up occurs when a transistor is switched off. Thanks in part to this efficient mode of operation, the researchers were able to reduce the energy loss by half relative to existing systems – whereby the device achieves an overall efficiency of a record 98.1 %.



With an efficiency rate for the two conversion stages of around 99 % each (upper two curves) and an overall efficiency rate of about 98 % (red curve), the ETH transformer is significantly better than a comparable industrial device. Rothmund et al.

Innovation as the ladder to success

This ground-breaking success was only possible thanks to a range of further innovations during the development of the solid-state transformer. For example, the researchers developed new control and protection concepts as well as a new method for measuring switching losses in the power transistors. Only this fundamental work made it possible to select the circuit structure and construction and finally the system's operating parameters with optimum efficiency and to determine the efficiency of the circuit very precisely. Another technical challenge was the insulation of the high voltage parts of the device. As the thermal conductivity of ordinary materials was too low for this application, the team used a special silicone as an insulator and developed a new method for calculating the medium-frequency losses in insulating materials.

A small device with great potential

With its outstanding performance features, the power electronic transformer from the ETH forge will allow for computer centres to be operated significantly more efficiently. But other systems that consume high amounts of electrical energy, such as the charging stations for electric cars mentioned above, can also benefit from this research. Above all, however, the new device demonstrates the potential of solid-state transformer technology to support the energy supply of the future.

Produkte aus diesem Projekt

- Smart transformer for the energy turnaround
  Date of publication: 01.01.18
- Highly Efficient 10kV SiC-Based Solid-State Transformers
  Date of publication: 01.01.18
- Smart All-SiC Solid-State Transformers
  Date of publication: 01.01.18
- Design and Experimental Analysis of a 10 kV SiC MOSFET Based 50 kHz Soft-Switching Single-Phase 3.8 kV AC / 400 V DC Solid-State Transformer
  Date of publication: 01.01.18

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All information provided on these pages corresponds to the status of knowledge as of 10.05.2019.