Energy
National Research Programmes 70 and 71

Project

SwiSS solid-state SiC transformer

A new transformer for the Swiss electricity grid of the future

A new transformer for the Swiss electricity grid of the future

In future, many decentralised renewable energy sources such as wind and photovoltaic plants will feed electricity into the grid. New transformers are needed in order to protect the grid from overload and ensure sufficient efficiency.

The electricity grid of the future must be able to meet new challenges – in particular the fluctuating supply of electricity from renewable sources makes new components necessary. *Source:* Pixabay

At a glance

- Renewable energy sources feed electricity irregularly into the grid.
- For example, the electricity fed into the grid from photovoltaic systems threatens to destabilise the power grid around the sunny midday period.
- New electronic transformers based on silicon carbide could help to solve this problem.

The phasing out of nuclear power with electricity from renewable energy sources in return – this is the abridged version of Energy Strategy 2050. However, while this objective can be stated in not so many words, it will have an impact on what is probably Switzerland's largest infrastructure: the electricity grid. With many additional photovoltaic and wind power plants, the dynamics of the Swiss electricity grid will change completely. Where a few central power plants used to provide all the energy, hundreds of thousands of small producers will in future feed electricity into the grid.

This causes two problems for the electricity grid. Firstly, the grid in its current form faced the threat of overload due to overvoltage – especially at midday when the sun is at its highest and many photovoltaic systems feed surplus energy into the grid. Secondly, the current local distribution grids, for example those of residential areas, are not prepared to cope with the larger voltage fluctuations due to the volatile

A small component with an important task

Both problems can be attributed to a very specific component: the transformer. This has the task of transforming high voltages into low voltages – or vice versa. On its journey from the power plants to households, the voltage is reduced by more than a thousand times: from 380,000 volts at the beginning to 230 volts – the voltage required by kettles, hairdryers and vacuum cleaners in our homes.

Transformers today are still made of copper and iron, just as they were 100 years ago. Via coils with different numbers of windings, transformers convert the electrical current from high to low voltages at a fixed voltage ratio. The fluctuating supply from photovoltaic and wind power plants cannot be compensated for by these traditional, inflexible components – and thus the voltage in the electricity grid is destabilised.

In order to master these challenges, new, more flexible transformers are required. These must be at least as efficient and reliable as the conventional models.

New material, new possibilities

Such flexible transformers are controlled electronically. The most suitable materials for this are semiconductors made from silicon carbide (SiC), as they achieve a high level of efficiency. Electronic transformers based on this as yet little researched material have the potential to meet the high demands in terms of flexibility, high efficiency and high switching speed that the grid of the future will bring.

In order to establish reliable, energy- and cost-efficient systems, however, the innovative material, its functionality and industrial manufacturing processes must be thoroughly researched and characterised.

This was the aim of the joint project “SwiSS Transformer”. In total, the project explores four aspects:

Sub-project 1. Material-related basics.

In order to manufacture efficient and reliable silicon-carbide-based power semiconductor devices, the properties of the material – as well as possible manufacturing problems – must be precisely understood. The large instruments of the Paul Scherrer Institute such as synchrotron and muon spectrometers are used for this purpose. The researchers used them to analyse thermally grown silicon dioxide layers and the silicon dioxide-silicon carbide interface. They found that the properties of the grown oxides strongly depend on the properties of the original SiC surface.

Sub-project 2. Development of a passive cooling system.

The new power electronic components become hot during operation and need to be cooled. An EPFL Lausanne research group has developed an efficient cooling system for this purpose that does not require fans or pumps and consumes no electricity itself. To this end, the researchers constructed a so-called thermosiphon – a closed system on one side of which are the power electronics components that are to be cooled. On the other side is the outside air to which the heat is emitted. A refrigerant dissipates heat from one side to the other.

Sub-project 3. Development and realisation of a transformer with the new silicon carbide technology.

Researchers at ETH Zurich developed and tested a prototype for a silicon-carbide-based transformer. The alternating current-direct current converter from 3,800 volts to 400 volts achieves a full load efficiency of 99 % and a power density of 3.8 kilowatts per litre (kW/L). In comparison to existing systems, only half of the losses are generated and the converter is twice as small.

Sub-project 4. Investigation of the possible application of SiC-based transformers in the electricity grid as part of Energy Strategy 2050.

In particular, a team of researchers from the University of Applied Sciences Northwestern Switzerland (FHNW) investigated the effects of the new technology on the overall stability of the grid and environmental sustainability. The results showed that with the innovative transformers photovoltaic systems with a total production capacity that even exceeds the targets of Switzerland’s Energy Strategy 2050 can be integrated in the investigated distribution grid.

The joint project shows that the new semiconductor material silicon carbide has the potential to improve the efficiency of power electronic systems. However, further research is needed to unlock the full potential in terms of efficiency and reliability.

Produkte aus diesem Projekt

- Interdisziplinäre Forschung entang einer Wertschöpffungskette
  Date of publication: 01.01.18
- Oft keine, dann wieder viel zu viel Energie
  Date of publication: 01.01.18
- Die Energiewende steckt noch in den Kinderschuhen
  Date of publication: 01.01.18
- Werden Trafos künftig zu Multifunktionstools?
  Date of publication: 01.01.18

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Project direction

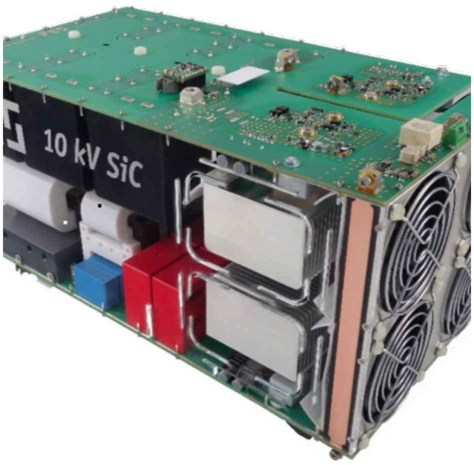
Connected projects

SiC solid-state transformer

A small component with great responsibility

Cooling of SiC solid-state transformer

Clever Cooling System for Power Electronics



Demonstrator of SiC solid-state transformer

Use electrical energy more efficiently with new solid-state transformers

SiC solid-state transformer in the grid

More scope for photovoltaics – thanks to new transformers

All information provided on these pages corresponds to the status of knowledge as of 22.05.2019.