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Ingenuity for life

Siemens innovates: Esters in HVDC transformers

Peak in our electrical research laboratory

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Innovation in HVDC transformers
In the long history of transformers, HVDC transformers are quite a young chapter. The innovation path of this product is more like an innovation highway: The units are becoming more powerful at the same or an even more compact size.

In 2008, for example, Siemens Transformers was the first supplier to successfully test an 800-kV HVDC transformer for a 5-GW HVDC substation. Since then, the power of 800-kV HVDC has been steadily increasing. Today 800 kV HVDC transformers are designed to operate at a transmission capacity of 10 GW.

Because the technology is evolving so fast, customers are not only ordering more powerful and efficient upgrades: Instead, they are requesting the same size as the old transformers that are being replaced.

Siemens Transformers is currently working on an order for the first 1,100-kV HVDC transformer to assist in the development of the Chinese infrastructure.

A technological leap forward
The evolution of HVDC transformers is founded on extensive research and development. Siemens Transformers operates its own electrical research laboratory so that it can test materials before they are used in actual projects.

When it comes to solid insulation, synthetic materials are already being used in HVDC transformers, including Nomex®, which is based on aramid fibers. However, solid materials are only compatible in areas where the influence of DC stress is very low or nonexistent.

Alternative fluid insulation materials have been increasingly employed for the last several years, and they have been used successfully up to the highest voltage levels in AC transformers. That is why Siemens Transformers began research to evaluate their characteristics and feasibility in HVDC units.

The outcome: It is possible to substitute mineral oil also in HVDC transformers up to a voltage level of 500 kV in the first instance. This means another pioneering step towards the future initiated by the innovation leader in transformers.

HVDC demonstrator in the electrical research laboratory at Siemens Transformers in Nuremberg, Germany

The future of HVDC: combining efficient energy transmission and biodegradable insulation fluid.

Characteristics tested by Siemens Transformers R&D
Several characteristics of ester fluids were evaluated in order to approve the use of esters in HVDC transformers:

- Conductivity of fluids and impregnated solid insulation
- Electrical stability of esters under DC stress and polarity reversal
- Electrical stability of the insulation system (fluid plus solids) under DC stress
- Prove the functionality of an insulation system using esters in DC applications

The tests focused on natural and synthetic ester fluids compared with mineral oil. All of the criteria described above were evaluated according to a qualification program for alternative insulation fluids.

Test results
The difference in the electrical stability of ester fluids compared with mineral oil was confirmed. The conductivity of esters is much higher than that of mineral oil. This is of great significance for the design of transformer insulation systems. The dielectric strength with DC stress and polarity reversal compared with the dielectric strength with AC stress was also tested. All insights gained in these studies were translated into rules and regulations for the design of an insulation system for HVDC transformers with alternative fluid insulation.

These rules were then confirmed by an experimental design that replicated an ester transformer insulation (HVDC ester demonstrator). Tests with DC stress up to +350 kV and polarity reversal up to ±300 kV were successfully performed.

Outlook: the environmentally friendly future of HVDC
Siemens Transformers has intensively driven the performance of HVDC transformers the last several years. Unit performance has been increased by 1.5 at the same size over the past eight years.

This is especially true for applications of this technology in urban areas or rough terrain, where size and eco-friendliness are of extreme importance. When it comes to the energy landscape of the future, the high thermal strength and biodegradability of esters can contribute to an efficient and eco-friendly outlook for HVDC transmission – in urban areas as well as offshore applications and in locations protected by environmental regulations.

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