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Modern insulating liquids for tap-changers and accessories

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Overview

Transformers rely on on-load tap-changers (OLTCs) or de-energized tap-changers (DETCs) to adjust voltage and maintain the stability of the grid in which they operate. Most of these transformers are filled with an insulating liquid, which must ensure:

- electrical insulation
- heat absorption
- appropriate lubrication
- compatibility with materials
- and, specifically for tap-changers, safe behavior under electric arc conditions

Mineral insulating oil has always been the standard liquid used in transformers, but there is a growing demand for less flammable and environmentally safe insulating liquids, especially for applications in urban areas and environmentally sensitive regions. Therefore, modern insulating liquids, such as esters, have become increasingly relevant in the global power sector.

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Different types of modern insulating liquids and their main characteristics

Currently, synthetic esters and natural esters (that meet standards such as IEC 61099 and IEC 62770) are the most widely used modern insulating liquids in transformers. Bio-based hydrocarbons (not petroleum-based) and gas-to-liquid (GTL) insulating oils are also emerging as viable modern insulating liquids for transformers.

HWMHs (High Molecular Weight Hydrocarbons), silicone oils, and certain gases are much less commonly used as insulating liquids and are applied in transformers for very specific niches. When using synthetic esters, natural esters, bio-based hydrocarbons, and GTL, special attention is required for the tap-changer, and Reinhausen should always be consulted regarding the application.

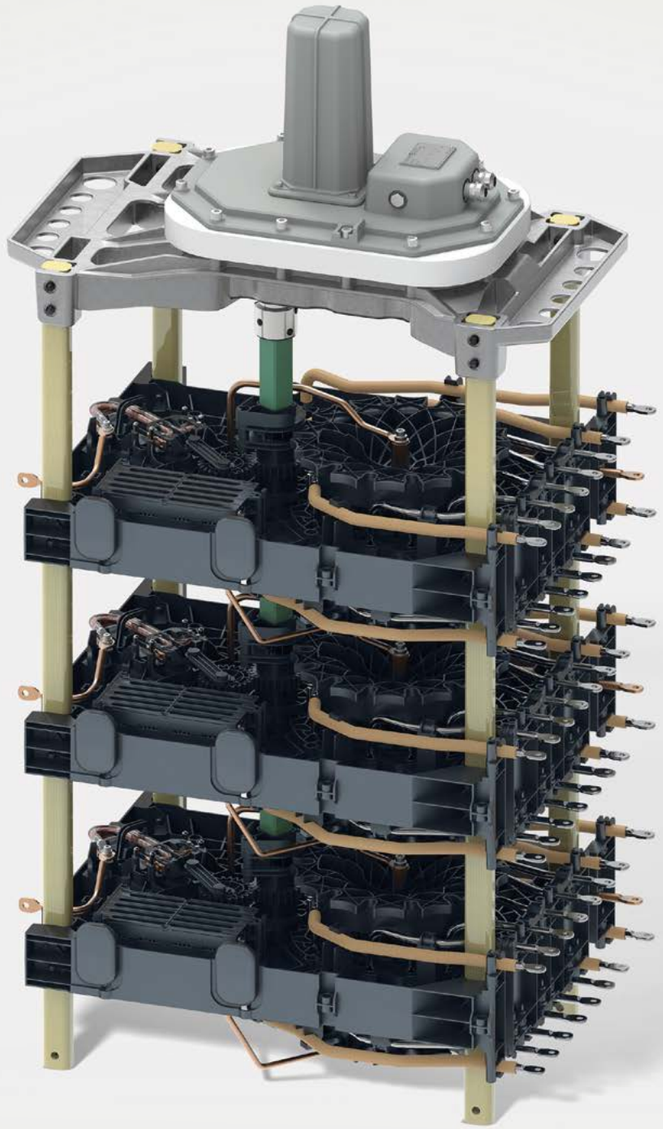
Recycled mineral insulating oils that meet the standards for new/unused oil (such as IEC 60296) can be used with Reinhausen tap-changers and, within the context of this document, are not considered a modern insulating liquid.

To issue the necessary approvals and ensure proper operation, Reinhausen must be informed of the specific type of modern insulating liquid intended for use with its products.

The main characteristics of modern insulating liquids for use with Reinhausen tap-changers are presented in the table opposite.

Insulating liquid	Main characteristics and relative comparison with mineral oil
Synthetic ester	– Chemical processing origin – Biodegradable – High fire safety – Moderate viscosity – Reduced performance at very low temperatures – Comparable oxidation stability; transformers and tap-changers may be of the “free-breathing” type
Natural ester	– Plant-based origin (soybean, rapeseed, sunflower, etc.) – Biodegradable – High fire safety – High viscosity – Reduced performance at very low temperatures – Low oxidation stability – requires hermetically sealed transformers and tap-changers
Bio-based hydrocarbon	– Renewable hydrocarbon – Biodegradable – Low viscosity – Comparable performance at very low temperatures – Comparable oxidation stability
Gas-to-liquid (GTL)	– Derived from hydrocarbons – Biodegradable – Low viscosity – Comparable performance at very low temperatures – Comparable oxidation stability

Requirements of the insulating liquid for tap-changers



From the perspective of the insulating liquid, tap-changers impose more severe conditions than the transformer itself, especially in the case of on-load tap-changers. The main requirements for an insulating liquid used in tap-changers are:

- Appropriate electrical insulation even in non-homogeneous geometries
- Efficient thermal dissipation for contacts and resistors
- Sufficient lubricity for 1.2 million operations and more
- Suitable viscosity to ensure correct switching operation
- Compatibility with materials (metals, insulators, elastomers, etc.)
- Free from corrosive sulfur to prevent deterioration of silver-plated contacts and to avoid copper corrosion

Traditional tap-changer models were originally designed for mineral oil, and the use of any modern insulating liquid must be carefully evaluated (Tap-Changer performance when using modern insulating liquids).

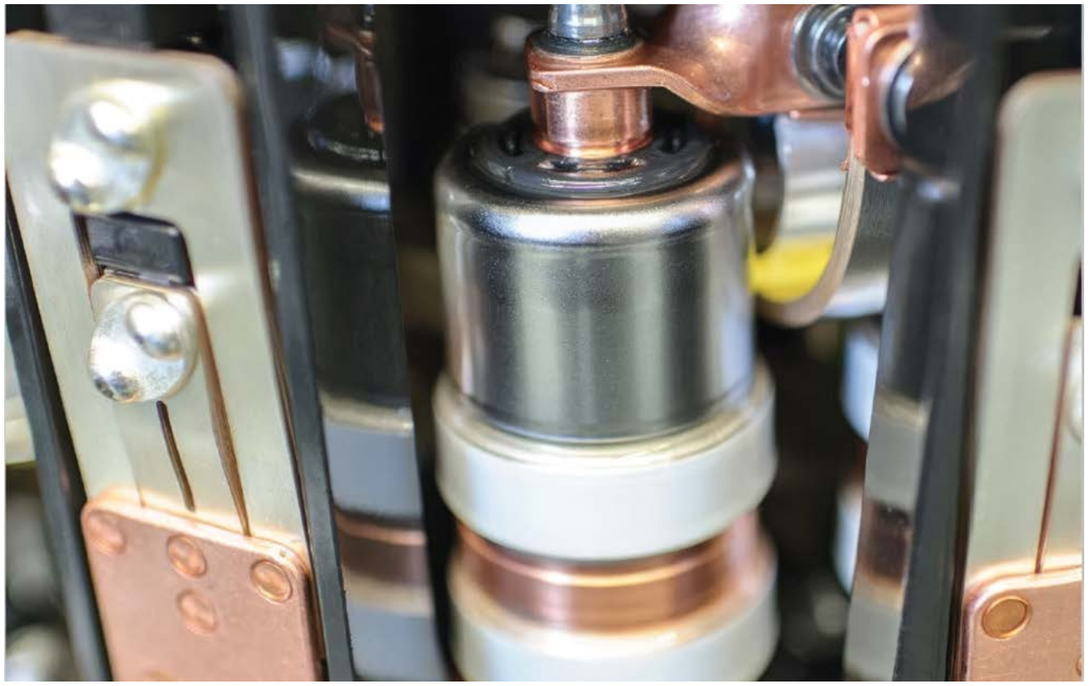
There are new integrated-type tap-changer models that have been specifically designed to operate with mineral oil, esters (synthetic and natural), bio-based hydrocarbons, or GTL.

Which tap-changers are suitable for modern insulating liquids

Reinhausen's guidelines are as follows:

- The arc occurs inside the vacuum interrupter, not in the insulating liquid, so the type of liquid has less impact on tap-changer operation
- Tap-changer maintenance is reduced
- Broad compatibility with synthetic esters, natural esters, bio-based hydrocarbons, and GTL
- As with OLTCs, Reinhausen DETCs can also be used with modern insulating liquids, subject to prior approval.

OLTCs equipped with vacuum technology (VACUTAP® and ECOTAP®), currently considered the market standard, are the recommended solution for use with modern insulating liquids!



Tap-changer performance when using modern insulating liquids

Although modern insulating liquids have physical and chemical characteristics distinct from those of mineral oil, Reinhausen's engineering team has already developed solutions to integrate this technology effectively. Properties such as electrical insulation, heat exchange, operating temperatures, electrical arcs, material compatibility, and sealing systems are addressed in the tap-changer design for maximum efficiency.

Electrical insulation

To maximize the potential of modern insulating liquids, the design of tap-changers employs rigorous voltage class sizing and appropriate component selection to ensure safe operation.

Thermal capacity

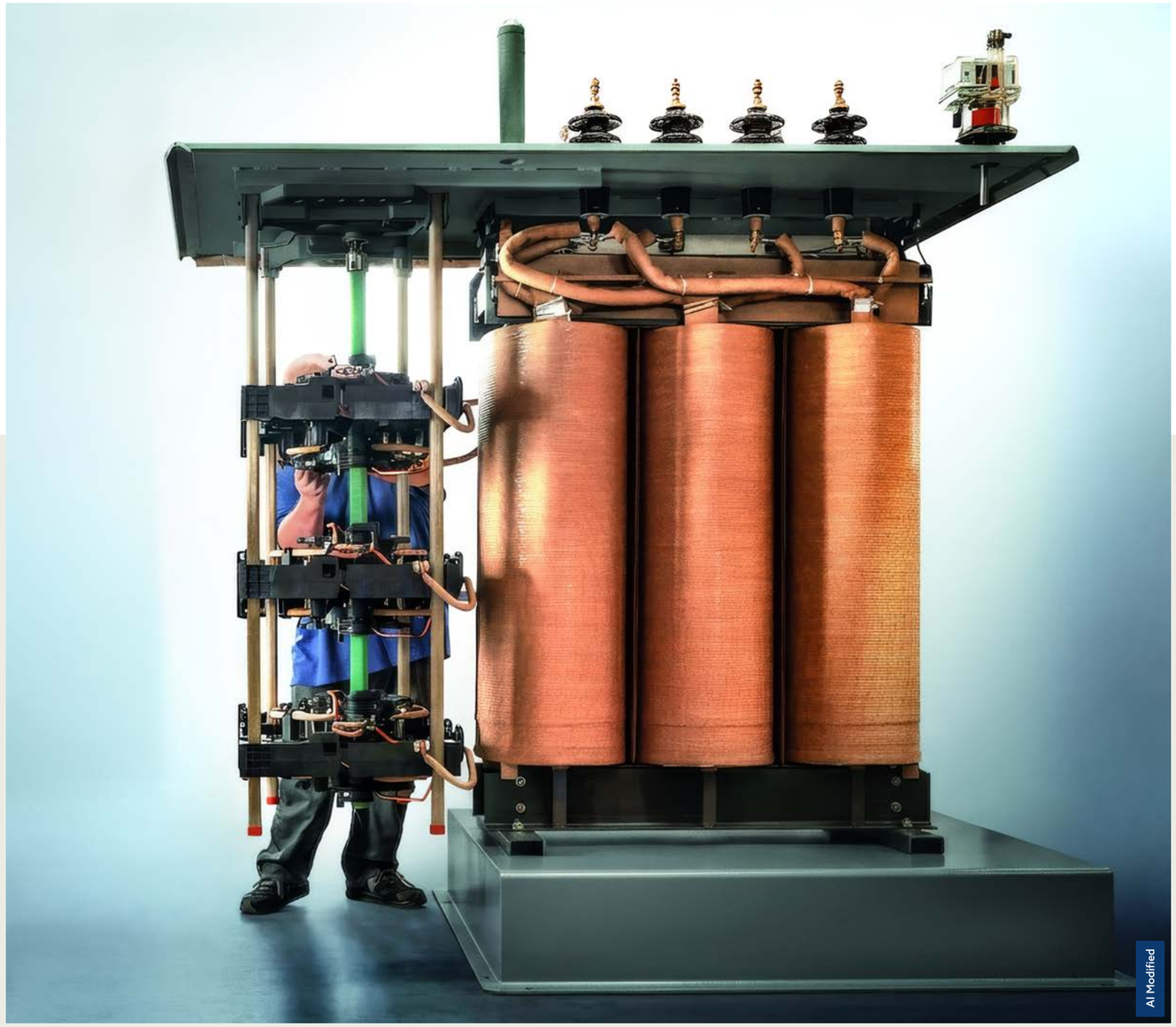
Esters have different thermal properties from mineral oil. Thus, minor adjustments are made to the tap-changer ratings accordingly.

Arc quenching capability

Since esters are more viscous, their arc-quenching capability differs. Through minor adjustments to the switching capacity or to the tie-in resistors, we ensure that each operation is performed with precision, while maintaining the required interruption capacity.

Operating temperature

Due to their higher viscosity, esters require special attention to ensure efficient operation at low temperatures. For GTL and bio-based hydrocarbons, extra caution is needed when operating at high temperatures due to the low viscosity of these liquids.



Material compatibility

Most of the materials used in tap-changers designed for mineral oil are also compatible with modern insulating liquids. However, gasket materials need to be replaced with specific elastomers (such as FKM/ Viton®) to provide superior compatibility in applications involving modern insulating liquids.

Sealing systems

To preserve the purity of natural esters, hermetically sealed systems need to be employed in Reinhausen tap-changers. This is necessary to protect the liquid from oxidation and safeguard the interior of the tap-changer against moisture ingress and external contaminants, ensuring an extremely stable internal environment.

Maintenance

The use of modern insulating liquids may require adjustments to some traditional tap-changer maintenance procedures, as certain characteristics differ from those of mineral oil. These differences can influence inspections, liquid evaluation criteria, and even handling during interventions.

The maintenance interval for OLTCs using modern insulating liquids is the same as for OLTCs operating in mineral oil, but maintenance involving a natural ester needs to be optimized to reduce exposure time to ambient air.
Therefore, it is essential to always follow specific guidelines for each type of liquid and consult Reinhausen's most up-to-date maintenance guide before performing any activity on the equipment.



Retrofilling transformers with esters

Retrofilling existing mineral oil-filled transformers with esters (synthetic and natural) is an effective way to enhance the safety and ecological properties of transformers. For transformers equipped with Reinhausen tap-changers, it is necessary to consult Reinhausen regarding the technical feasibility of replacing the insulating liquid.

In the case of transformers with tap-changers that do not utilize vacuum technology (OILTAP®), in addition to Reinhausen's technical assessment, esters may only be used to retrofit the transformer tank. The internal compartment of the OILTAP® tap-changer must remain filled with mineral oil. This is because arcing behavior in esters is different from that in mineral oil, which affects the arc-breaking performance of the diverter.

More information about retrofilling can be found in IEC TR 63646-Guideline for retrofilling mineral oil-immersed transformers up to 72.5 kV with ester-based insulating liquids.

Accessories

The Reinhausen Group offers accessories for:

monitoring

+

protection

+

control

+

automation of transformers

designed to be compatible with modern insulating liquids.

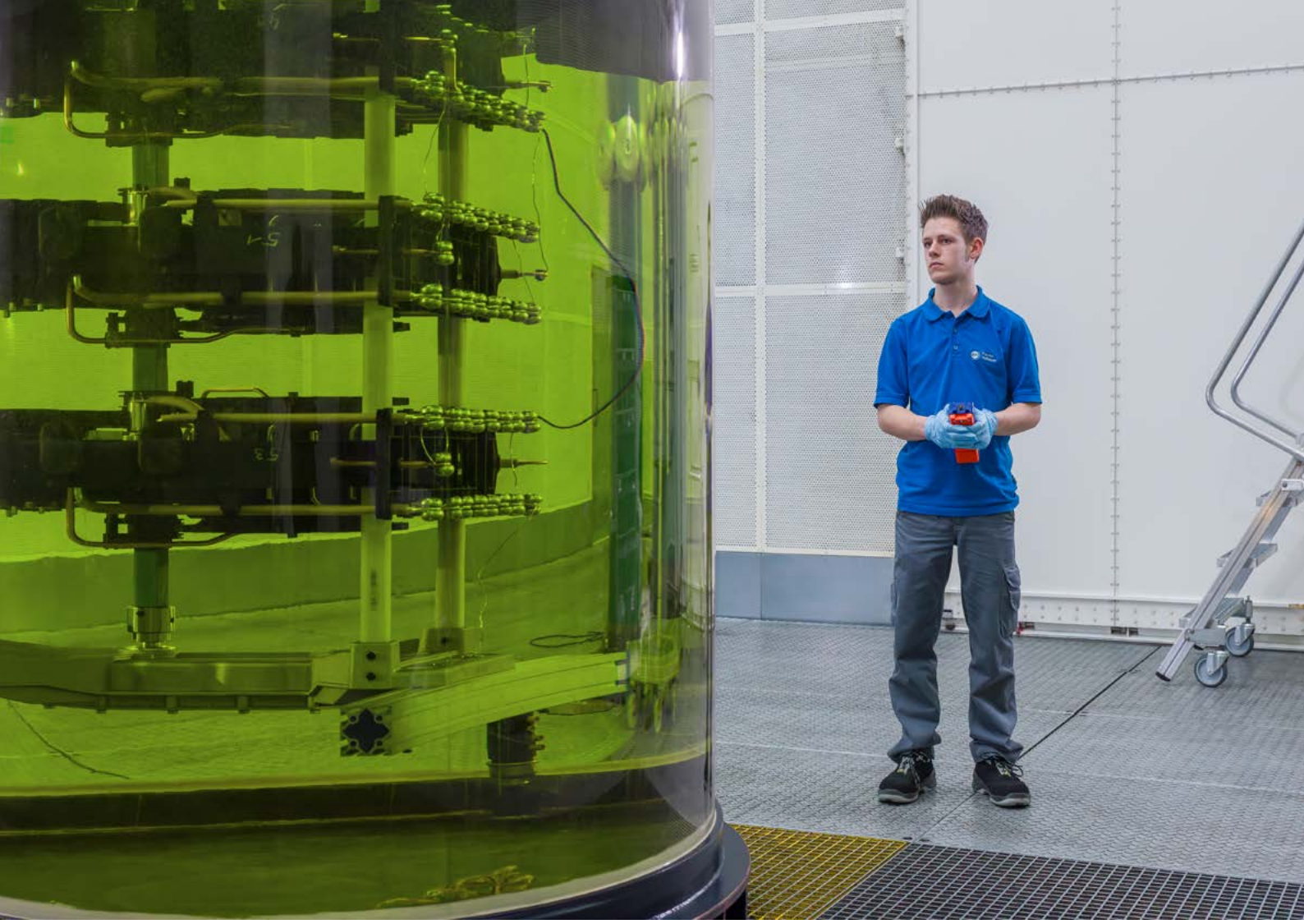


Final analysis

When it comes to tap-changers and accessories designed for operation with modern insulating liquids, Reinhausen has decades of experience and has supplied thousands of units worldwide for a wide range of applications.

We continually qualify tap-changers and accessories with new insulating liquids that become available on the market. To view the insulating liquids and brands already tested and evaluated by Reinhausen, please visit the webpage.

→ More information



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