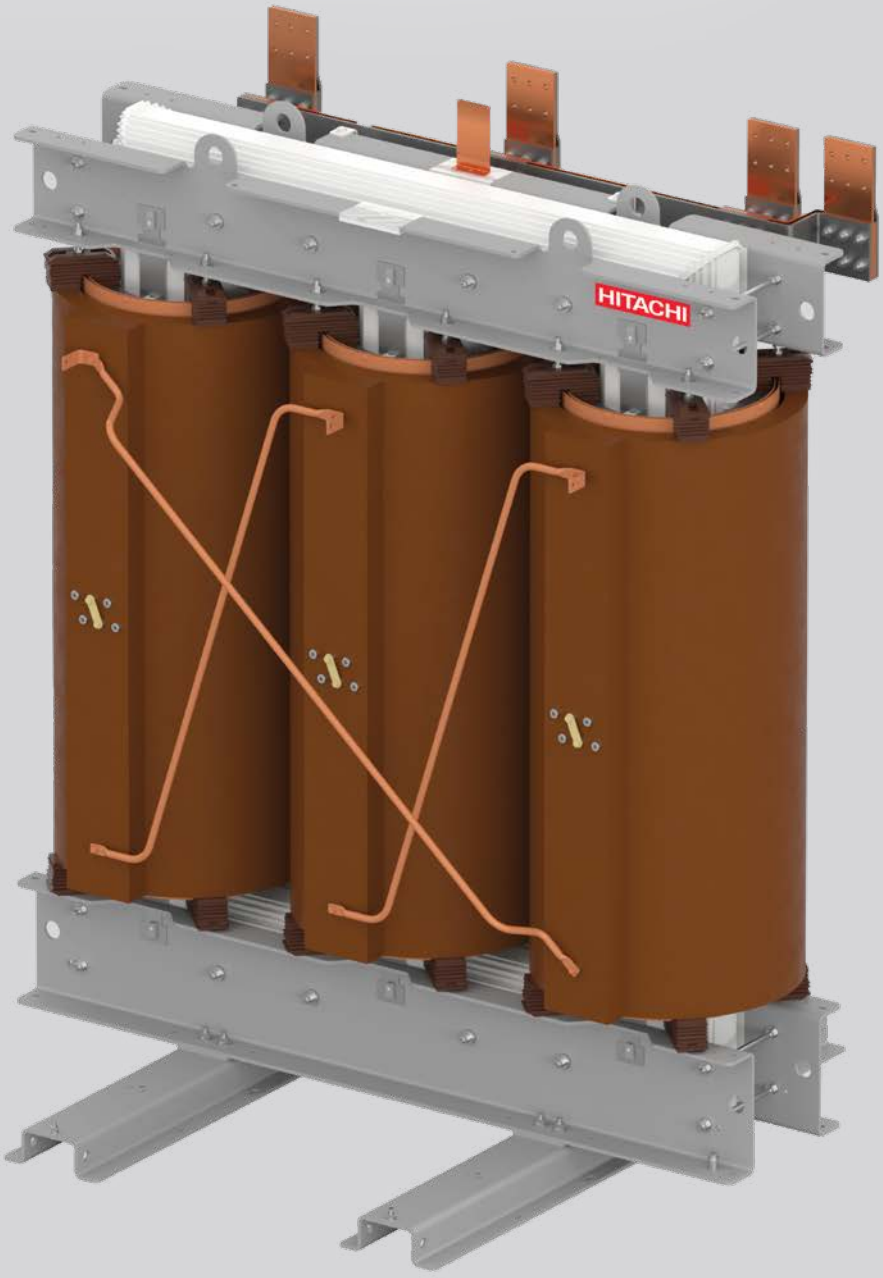
The technology neutrality conundrum

Could dry and liquid-immersed transformers ever become technology neutral?



Safety cannot be compromised: The inherent challenges considering the merits of different technologies within a technology neutral approach

Technology neutrality brings the inherent challenge of unambiguously and appropriately accounting for the merits of the different technologies beyond energy efficiency

Introduction

Transformers are built to be very efficient, and their efficiency yields energy savings that are spread over the course of their typical service lifespans of 30 years or more.

The current set of regulations that relates to energy efficiency applicable to transformers is known as the Minimum Energy Performance Standards (MEPS). Those policy instruments and programs are aimed at ensuring the adoption and use of high-efficiency transformers.

Across the globe, multiple transformer MEPS are in place, differing between regions and countries such as the European Union, the US, Canada, China, India, Japan, Brazil, Australia and New Zealand. The European Union's mandatory MEPS differentiates transformers based on rated power, rated voltage, and technology.

In current policy debates, technology neutrality is cited as one criterion that should be considered when informing the design of regulatory instruments. In the context of transformers, technology neutrality refers to considering all transformer technologies as equal for establishing regulations and standards.

Some advocates of the technology-neutral approach favour requiring liquid-immersed and dry-type transformers to be equally efficient. However, focusing exclusively on energy efficiency and losses might sidestep the consideration of other performance aspects of transformers.

Different transformer technologies possess distinct performances and merits extending beyond energy efficiency to be considered depending on the application. For example, while liquid-immersed transformers generally operate with higher energy efficiency for the same ratings, dry-type transformers provide advantages related to environmental protection, safety, and fire performance.

Technology neutrality brings the inherent challenge of unambiguously and appropriately accounting for the merits of the different technologies beyond energy efficiency, as it increases complexity when performances other than losses are to be considered.

A transformer's fire behaviour is especially relevant and crucial for that, as no approach, regulation, or standard can be defined at the expense of safety.

The technology neutrality conundrum should then first be addressed to answer the question of what technology neutrality really means for transformers: Is it to equalize losses or energy efficiency? Equalize fire safety performance? Look for the optimum TCO (total cost of ownership)?

Hitachi Energy, with a combined heritage of more than 250 years and the largest base of installed transformers, firmly believes that advancing efficiency is a fundamental pillar of sustainability

The minimum carbon footprint? What is the weight of other sustainability-related aspects? Are there other implications, such as supply chain and availability of materials, system complexity, increased size and dimensions?

In light of technology neutrality and using reductio ad absurdum, as mathematicians use to validate and develop their theories, we could propose to require the same fire safety performance regardless of transformer technology, as safety is the most critical priority, instead of only attempting to equate energy efficiency across transformer categories.

This article aims to emphasize the complexity of the issue and the significance of adopting a holistic approach to spark and encourage discussion in the industry.

Hitachi Energy's contribution to energy efficiency

Hitachi Energy, with a combined heritage of more than 250 years and the largest base of installed transformers, which includes over 2.5 million and 325 thousand distribution and dry-type transformers, respectively, firmly believes that advancing efficiency is a fundamental pillar of sustainability.

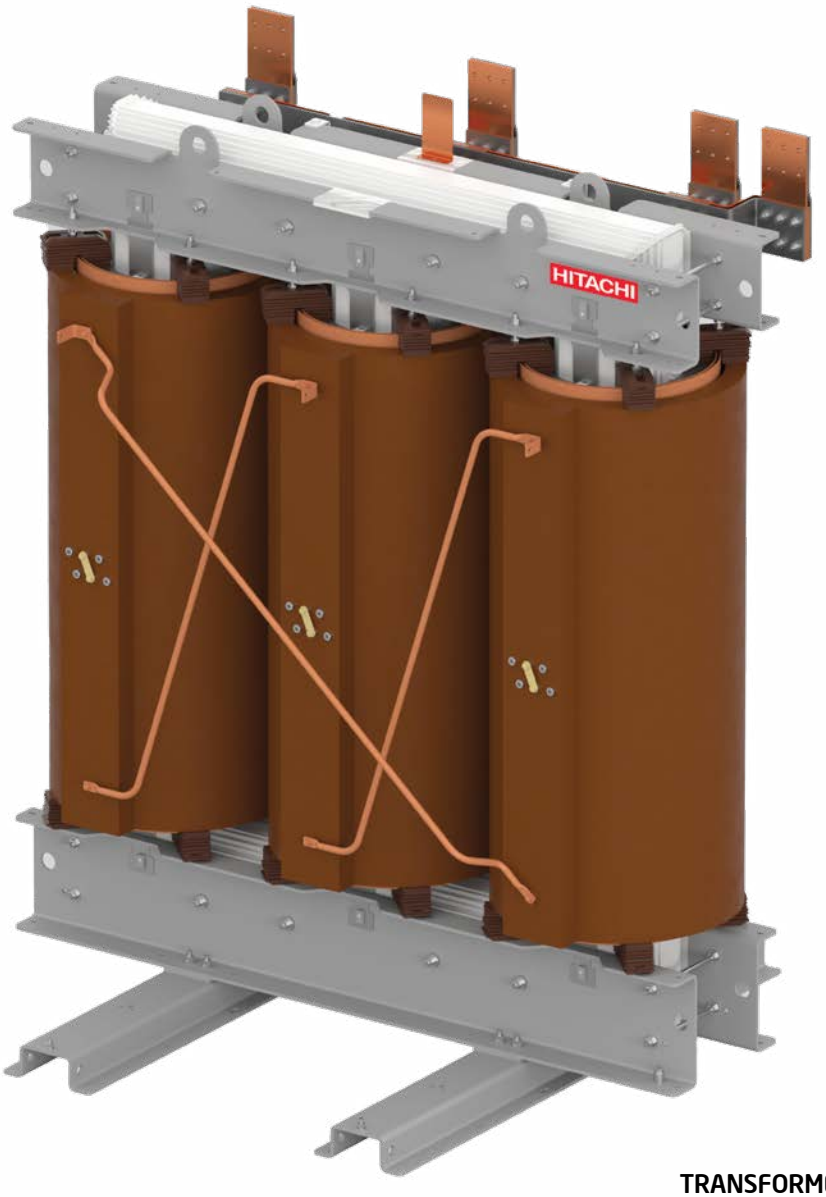
For example, the company has been actively enabling EU policy initiatives like the EU Green Deal, Fit for 55, and Repower EU in Europe.

With an extensive track record in developing different transformer technologies, their materials, and components, but also their design and manufacturing processes, we actively and constantly engage in the design optimization of our dry and liquid-immersed transformers to minimize their carbon footprint and thus contribute to a more sustainable and energy-efficient future while preserving the reliability and availability of our equipment.

With safety as our first priority, we continue to dedicate our best efforts to serve our customers and the industry while advancing our transformers' efficiency and technical and operational performance.

Hitachi Energy's is adopting a holistic sustainability perspective, wherein we review and assess all aspects of our value chain, laying particular emphasis on the following four:

- Decarbonization: the reduction of our transformers' carbon footprint with emphasis on loss reduction according to the energy mix; reduction of the emissions associated with the whole value chain, raw materials, suppliers, manufacturing operations, and end of life.



While aiming for reliability, efficiency and sustainability, one fundamental aspect that Hitachi Energy never compromises is safety, which directly ties in with their commitment to people

- Protection of ecosystems.
- Enhanced safety to protect people and equipment, with fire safety claiming highest priority.
- The responsible use of resources, with recyclability and circularity playing an important role.

Liquid-immersed distribution and dry-type transformers

It is well known in the industry that there are two main categories of transformers for distribution-level applications: liquid-immersed (using mineral oil or alternative fluids such as synthetic or natural esters) and dry-type.

Liquid-immersed transformers are the most compact and typically regarded as cost-effective, while dry-type transformers are preferred in environments where fire safety is of particular concern, such as buildings and hospitals, underground applications, metro and railway stations, industries, onboard marine operations, and several others, due to their differentiated value proposition: They have reduced environmental contamination risks with zero risk of leakage of flammable or contaminating substances, having the lowest fire load.

Both technologies are widely used, and customers and end users make their choices based on their needs and the perceived value of the technology for the desired application.

While aiming for reliability, efficiency, and sustainability, one fundamental aspect that Hitachi Energy never compromises is safety, which directly ties in with our commitment to people. The focus on safety is embedded in our company's DNA as a socially responsible and sustainable organization. It is our duty to offer the most suitable transformer technology while fulfilling their requirements within the requested areas of application.

Concerns on the practicality, effectiveness, and possible consequences of technology neutrality

Transformer technologies have evolved from a complex mix of solving dielectric, thermal, mechanical, and magnetic challenges efficiently. Those technologies have been refined and optimized over the years to address design, manufacturing, operational, and application challenges in a technical and economically sound manner.

So, what does technology neutrality really mean? Is neutrality intended for use in equalizing losses (or energy efficiency) of two completely different concepts of transformer construction when the existing efficiency regulations already set the standards at a high level?

Special consideration deserves to be given to analyzing the benefits of marginal improvements in the efficiency of transformers, especially when a very high efficiency level has already been set, as recognized by the Tier 2 European regulations.

This takes us back to the question we sought to raise in the introductory paragraphs of this paper: As safety is of the highest priority, *should the same fire safety performance levels be demanded, regardless of the transformer technology?*

The argument gets even more complex when lowering losses as it implies using larger quantities of materials like electrical steel, copper, aluminum, carbon steel, and insulation; this requires consideration from both the energy efficiency and broader sustainability perspectives.

Another essential aspect pertains to evaluation beyond the standalone transformer as an integral part of a more extensive system and complex operational environment, where the total cost of ownership enters into play.

Therefore, the fire safety performance is a significant aspect to be considered within the technology neutrality approach, in addition to weighting other different performances.

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Dry-type transformers' high fire safety standards merit differentiated consideration

While liquid-immersed transformers generally operate with higher energy efficiency, dry-type transformers meet Tier 2 requirements and provide invaluable safety and fire performance advantages.

These functionalities are highly valued by end-users and align with the objectives set forth in Directive 2009/125 EC, as follows.

1. Safety and fire performance

The fire risk of ester fluid-filled transformers is lower compared to those filled with mineral oil. Natural ester fluids are classified as "less flammable" dielectric insulating fluids, which undoubtedly improve fire safety. It is important to emphasize that being "less flammable" means a higher fire point, even if still flammable.

In line with global standards, regulations and guidelines, rigorous fire behaviour tests have been conducted for dry-type transformers for several decades to prove their superior fire point temperatures and lower fire loads when compared to liquid-immersed transformers.

Typically, the order of magnitude of the fire load of dry-type transformers is one-third of the equivalent of liquid-immersed (ester fluid) transformers. Additionally, they do not contain any liquid material, eliminating the risk of spreading fire.

Accordingly, dry-type transformers play a critical role in ensuring fire safety across various applications, including but not limited to hospitals, airports, metros/subways, office buildings, stadiums, nuclear power plants, hydropower plants, wind turbines and marine vessels such as cruise ships, ice breakers, and navy vessels.

Dry-type transformers possess distinct benefits when compared to liquid-immersed transformers in terms of several fire safety-related characteristics, such as fire load, smoke generation, and the elimination of spillage

2. Risk of leakage and liquid spills

Liquid-immersed transformers present the potential risk of soil and water contamination during use and throughout their lifecycle in case of leaks (manufacturing, transportation, and disposal).

While these risks are adequately managed through strict industry standards and high-quality manufacturing methods, by contrast, dry-type transformers eliminate this risk entirely.

Dry-type transformers possess distinct benefits when compared to liquid-immersed transformers in terms of several fire safety-related parameters and attributes, such as fire load, smoke generation, and the elimination of spillage.

The fire behaviour test defined in IEC 60076-11 is the method used for the assessment of fire performance and levels of emission of toxic substances and opaque smoke. The F1-class fire behaviour test is conducted in a laboratory test chamber under the International Electrotechnical Commission's (IEC) specified conditions; they include predefined dimensions, temperature levels, heat sources and a chimney with an air-inlet duct. This test verifies that the transformer's contribution to feeding an external fire is negligible and that it releases limited quantities of harmful gases and substances. During the test, temperature levels of the transformer are taken in several parts, and the transmission of visible light and air and gas flow rates are measured. After the test, a report is prepared that provides the results of the test and compares them with the standards based on the rise in the temperature of the gases and the arithmetic mean of the optical transmission factor of light.

This fire behaviour test emphasizes a transformer's ability to maintain safety in the event of a fire and protect both personnel and the surrounding environment. Such a test is not defined for liquid-immersed transformers. Instead, to protect the environment, alternative methods are commonly used for liquid-immersed transformers. These methods include installing firewalls and separators, utilizing water-based fire protection systems, and implementing lightning protection on

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site. Additional devices are employed to reduce potential transformer failure rates to further enhance protection. These devices are circuit breakers or other components protecting the transformer from earthing faults, over-current, voltage, and pressure. While some of these devices can also be used for dry-type transformers, they help reduce fire risk in liquid-immersed transformers by diminishing failure risks and the risk of tank rupture, which indirectly helps to avoid explosions and oil spills.

However, the ultimate decision lies with the transformer buyer or end user, who must weigh their willingness to pay for the additional installation of fire protection systems while being aware of the superior safety of dry-type transformers.

For the above reasons, installing dry-type transformers in locations such as hospitals, airports, metros/subways, office buildings, stadiums, nuclear power plants, hydropower plants, wind turbines and marine vessels such as cruise ships, ice breakers, and navy vessels, is not just a wise choice, it is a strategic decision that prioritizes safety above any other aspect.

Rethinking and reinventing the technology-neutral approach for transformers

This article has presented the complexity of technology neutrality for transformers and the significance of adopting a holistic approach to encourage discussion in the industry.

Technology neutrality brings the inherent challenge of unambiguously and appropriately accounting for the merits of the different technologies beyond energy efficiency, as it increases complexity when performances other than losses are to be considered.

Hitachi Energy is strongly concerned about the potential adoption of a technology-neutral approach as proposed within the European Tier 3 Energy Efficiency Requirements for Transformers, as it is foreseen that it could require liquid-immersed and dry-type transformers to be equally efficient and also treat ester fluid-filled liquid-immersed transformers the same as dry-type transformers from a safety perspective, instead of weighting their respective performances accordingly.

We suggest carefully reconsidering the technology-neutral approach to avoid unintended consequences, as focusing exclusively on energy efficiency and losses might sidestep the consideration of other relevant performance aspects of transformers beyond energy efficiency, like fire safety performance.

While aiming for reliability, efficiency, and sustainability, one fundamental aspect that Hitachi Energy never compromises is safety, which is directly tied to our commitment to people.

While maintaining adequate levels of energy efficiency in transformers, keeping proper, efficient, and differentiated technological standards will facilitate the consideration of distinct functionalities and advantages while highlighting the importance of continued market availability of different, well-established transformer technologies, ensuring the best outcomes for end-users, safety, and the environment.

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Discover more about Hitachi Energy's distribution transformers

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