

Why Transformer Fluids are Becoming Critical Grid Assets

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The power grid is evolving faster than ever before. As countries accelerate the transition towards renewable energy, electrification and digital infrastructure, transformers are being asked to operate under increasingly demanding conditions. They must accommodate higher voltages, variable renewable energy inputs, harsher operating environments and rising expectations for efficiency, safety and reliability. In this changing landscape, transformer fluids have evolved from being a routine maintenance consumable into a strategic enabler of grid resilience, asset longevity and operational performance.

The transformer oil industry has undergone significant evolution over the past six decades, driven by changing power infrastructure requirements, technological advancements and increasing demand for reliable electrical networks globally. Today, the global transformer oil market continues to expand, supported by growing electricity demand, grid modernisation initiatives and the expansion of transmission infrastructure across emerging economies.

This transformation is reflected in the global transformer oil market, which is estimated at approximately US\$3.6 billion in 2026 and projected to reach US\$5.4 billion by 2033. Utilities, industries and transformer manufacturers increasingly recognise that insulating fluids play a critical role in determining the reliability, efficiency and lifecycle cost of one of the grid's most valuable assets.

Transformers in Transition: Adapting to a New Grid Reality

Transformers remain among the most critical assets within the electricity ecosystem, connecting generation, transmission and distribution while increasingly integrating renewable energy into national grids. Today's transformers face significantly greater demands than those installed even a decade ago. Variable loading, rapid cycling, increased thermal stress, higher operating voltages and more stringent environmental standards have fundamentally changed operating conditions.

These challenges are particularly evident in solar and wind projects, where intermittent generation makes transformers indispensable interfaces between renewable generation and the transmission network. Under these conditions, the fluid inside the transformer performs far more than a cooling function. It must provide electrical insulation, dissipate heat efficiently, suppress partial discharge and preserve the integrity of solid insulation throughout decades of operation.

Why Transformer Oil has become a Mission-Critical Material

Transformer oil performs several critical functions simultaneously. It insulates high-voltage components, transfers heat away from windings, suppresses electrical discharge and protects cellulose insulation from degradation. In conventional applications, mineral oils have reliably fulfilled these requirements. However, modern applications - including High Voltage Direct Current (HVDC) systems, inverter-duty transformers (IDTs) and ultra-high-voltage transmission infrastructure - place substantially greater demands on fluid performance.

When insulating fluids fail to perform, the consequences extend well beyond the transformer itself. Accelerated ageing of cellulose insulation reduces dielectric strength, increases maintenance frequency, raises the risk of unexpected failures and shortens equipment life. For utilities and industries, these technical failures translate directly into higher operating costs, reduced network reliability, warranty exposure and unplanned outages.

Consequently, transformer oils are increasingly evaluated not simply as consumables but as long-term investments that influence the total cost of ownership of critical electrical assets.

HVDC Transformer Oils

The high-voltage direct current (HVDC) transformer oil segment represents one of the most technically demanding applications in the speciality oils industry. Success in this segment requires advanced product development, stringent manufacturing standards and decades of accumulated technical expertise. Within India, only a handful of manufacturers have achieved the capability to produce HVDC-grade transformer oils, a distinction that reflects the ability to consistently achieve extremely high purity levels, implement rigorous quality controls and comply with the demanding technical standards required by modern HVDC infrastructure.

As HVDC transmission expands globally to support renewable energy integration and long-distance power transfer, fluid performance requirements continue to intensify. Projects demand exceptional dielectric characteristics, oxidation stability, moisture management and manufacturing traceability. Suppliers capable of supporting OEM qualification, technical specification and project commissioning therefore become strategic partners rather than commodity vendors.

The HVDC transformer oil market is expected to grow in tandem with investments in long-distance power transmission, renewable energy integration and cross-border electricity networks. As India and other emerging economies expand their transmission infrastructure, the demand for high-performance HVDC-grade oils is projected to increase, creating opportunities for APAR with the technical capability and quality systems to serve this specialised segment.

Synthetic Ester Fluids and the Renewable Energy Shift

One of the most significant developments in transformer insulation technology has been the growing adoption of synthetic ester fluids for renewable energy infrastructure.

Compared with conventional mineral oils, synthetic esters offer several important advantages. Their exceptionally high fire point significantly reduces fire risk, while enhanced biodegradability improves environmental performance. They also exhibit excellent moisture tolerance and maintain strong dielectric properties under demanding operating conditions.

These characteristics make ester-based fluids particularly well suited to inverter-duty transformers used in solar installations, where transformers frequently operate under highly variable loads in remote locations.

A notable example is the Maharashtra State Power Generation Company Limited (MSPGCL) programme, which specified synthetic ester fluid for approximately 300 - 400 inverter-duty transformers across multiple solar projects.

Key technical requirements for HVDC-grade transformer oils include a fire point exceeding 300°C (K3 classification), full biodegradability and compliance with globally recognised safety certifications. These specifications reflect the demanding operating conditions of modern HVDC infrastructure, where reliability, environmental compliance and operational safety are paramount.

The qualification process typically involves extensive testing, field trials and validation by independent laboratories to ensure that the oils meet the stringent performance requirements of HVDC applications. This collaborative approach

between manufacturers, OEMs and end-users has become increasingly common in the speciality oils industry, as technical partnerships play a critical role in developing application-specific solutions for complex power infrastructure projects.

Nearly a year of successful field performance has further validated the technology, with ester-filled inverter-duty transformers demonstrating reliable cooling and insulation under varying environmental and operating conditions.

Delivering at Scale in Complex Project Environments

Large infrastructure projects involve much more than product supply. Successful implementation requires technical approvals, vendor qualification, OEM collaboration, logistics coordination and commissioning support.

For instance, the participation of speciality oil manufacturers such as APAR in the Maharashtra State Power Generation Company Limited programme illustrates how these capabilities come together to drive industry advancement. Through technical engagement, qualification testing and project support, manufacturers have helped accelerate the adoption of synthetic ester technology while reducing implementation risk for utilities and developers.

Such programmes serve as important catalysts for technology adoption, demonstrating the viability of advanced solutions in real-world applications. By working closely with utilities, OEMs and project stakeholders, manufacturers can address technical challenges, validate performance claims and build confidence in new technologies.

Field Performance Builds Confidence

Ultimately, field performance remains the strongest measure of technical credibility.

Laboratory testing establishes compliance, but long-term operational success demonstrates real-world value. The successful operation of ester-filled inverter-duty transformers across Maharashtra's solar projects provides utilities and OEMs with tangible evidence that advanced transformer fluids can deliver improved safety, reliability and operational performance under demanding conditions.

Naphthenic Oils Continue to Play a Critical Role

While synthetic esters continue to gain momentum, naphthenic mineral oils remain indispensable across much of the transformer industry.

Their long history of reliable performance, predictable behaviour and proven economics make them the preferred solution for many utilities and industrial users managing extensive transformer fleets.

Naphthenic transformer oils, backed by globally recognised approvals and certifications, continue to play a critical role in the power sector by providing customers with confidence in product consistency, manufacturing quality and long-term operational reliability.

Condition Monitoring: The Next Frontier

The future of transformer fluids extends beyond chemistry into asset intelligence.

Condition monitoring programmes enable utilities to analyse oxidation products, moisture content, acidity and dielectric strength throughout the transformer's service life. These insights allow maintenance teams to predict failures, optimise maintenance schedules and extend asset life through data-driven decision making.

For specialist fluid suppliers, condition monitoring transforms a transactional relationship into a long-term technical partnership. Rather than simply supplying oil, companies increasingly contribute to asset management strategies that improve reliability and reduce lifecycle costs.

Powering Tomorrow's Grid

The future electricity grid will be more complex than ever before. Greater renewable integration, electrification, digitalisation and expanding transmission infrastructure will require transformers capable of operating safely and reliably under increasingly demanding conditions.

Meeting these challenges will require transformer fluids that combine exceptional dielectric performance, thermal stability, moisture management, environmental responsibility and long-term reliability.

Through a comprehensive portfolio spanning HVDC-grade fluids, synthetic ester technology and certified naphthenic oils, India's speciality oils sector is helping customers address evolving power infrastructure requirements while supporting the transition towards cleaner and more resilient energy systems. These technologies power some of the world's most critical infrastructure, enabling utilities and industries to build cleaner energy systems, stronger grids and more reliable electricity networks that meet the demands of modern power infrastructure.

As power systems continue to evolve, the role of transformer fluids will only become more significant. The companies that lead the future will be those that combine product innovation with manufacturing excellence, technical expertise and lifecycle support. By integrating advanced fluid technology with global manufacturing capabilities and decades of engineering experience, leading speciality oil manufacturers in India are positioning themselves not simply as suppliers of transformer oils, but as trusted partners in building the resilient grids of tomorrow.

About the Author:

Rishabh Desai is a Whole-time Director at APAR Industries Limited and Director at APAR Petroleum Specialities FZE (PSF), UAE. A graduate of Babson College, he has played a pivotal role in establishing and scaling APAR's specialty oils business globally. Under his leadership, PSF doubled production capacity and expanded exports to over 40 countries. Recognized for his entrepreneurial vision and strategic leadership, he was featured in the 2024 Hurun India Under 35 list, celebrating India's most promising young business leaders.