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SAFETY INSIDE

REDUCING RISK:

how ester transformer fluids are helping insurers

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TRANSFORMERS PRESENT A KEY CHALLENGE FOR RISK MANAGERS AND INSURERS. THIS WHITEPAPER EXPLORES THE EFFECTS OF INCREASED DEMANDS ON THE POWER TRANSMISSION AND DISTRIBUTION NETWORK. IT LOOKS AT HOW THE ENERGY INSURANCE INDUSTRY CAN MANAGE THE RISKS PRESENTED BY TRANSFORMERS THROUGH A STRATEGIC ASSET MANAGEMENT PLAN, AND HOW THE USE OF ESTER-BASED DIELECTRIC FLUID CAN HELP TO MINIMISE IMPACT ON THE MARKET.

INTRODUCTION

According to the World Energy Outlook, electricity demand will likely rise by more than two thirds between 2011 and 2035[1]. Particularly in developed markets and regions across the world, this has already led to an over-reliance on electricity, with many businesses and individuals taking its uninterrupted supply for granted. However, the inevitable outcome of powering our daily lives has meant an increased strain on energy infrastructure – and with this, comes risk.

TRANSFORMER LIFECYCLES

Strong industrial growth between the 1950s and 1980s signalled the start of increased investment in energy infrastructure, with new power networks being deployed to meet the growing demand for electricity. However, an expanding global population, increased urbanisation and growing per capita electrical usage is causing energy consumption to grow at a faster rate than the existing infrastructure can satisfy, putting pressure on power transmission and distribution equipment. With the majority of equipment engineered and installed during the boom growth years, many industrial transformers are now approaching the final phase of their lifecycle, which can result in substantial costs to upgrade or replace ageing infrastructure. Plus, the decentralised nature of distributed power generation, such as solar and wind farms, is creating additional and unforeseen challenges.

> Transformers are expected to operate under 'ideal conditions' for 30-40 years, or 20-25 years for industrial transformers – meaning that much of the infrastructure installed between the 1950s and 1980s will now be in the final phase of its lifecycle.

Transformers are an essential part of power distribution. Found in every industry and sector, transformers either step the voltage up or down, as required – to ensure an efficient flow of electricity. For example, power stations usually generate electricity at 25,000 volts (25kV), but to ensure maximum efficiency and prevent excess energy from being lost during transmission over long distances, transformers are used to step up the voltage to 420kV. Once the power reaches its final destination, such as a house, office building or manufacturing facility, it is stepped back down to a manageable level of 240V.

A HIGH-RISK ASSET

Assets such as transformers are particularly high-risk, with mechanical and electrical failures a key cause of unplanned outages in power transmission and distribution. The consequences of a transformer failure could range from the lights going out, to production equipment stopping mid-cycle, or in severe cases, a fire. Transformers are regularly cited as one of the top five high-risk assets[2] – a fact that is making the energy insurance industry look to alternative options to safeguard networks and reduce the likelihood of expensive claims. Importantly, understanding asset management and implementing a risk matrix to recognise the potential safety and financial costs is crucial to reducing the impact of transformer failure. As well as the strain placed on the components due to ageing infrastructure, a number of unexpected events can cause units to fail; design defects, voltage surges and vandalism, as well as environmental damage, such as lightning strikes or floods, all resulting in costly claims.

INDUSTRY CHALLENGES

The damage to transformers can be severe, often leading to the ignition of the mineral oil dielectric cooling fluid, which can quickly create an intense fire that can result in catastrophic damage, and in some cases, loss of life. In addition, failure of external equipment, such as a mineral oil filled bushing or on-load tap changers, can lead to the mineral oil in the main tank igniting. Damaging not only the unit itself, a fire of such proportions can also spread rapidly, putting the environment, any adjacent property, and people at risk.

The potential danger of transformer failures can have a ripple effect on production operations. The time to replace a failed unit is significant and can take several days, resulting in costly production downtime for manufacturing facilities. Data from commercial property insurance company, FM Global, revealed transformer loss ranked third amongst its clients' top five losses[3].

FM Global highlighted that between 2008 and 2013, damage to power transformers cost its clients a combined $339 million in lost revenue[4].

A SAFE ALTERNATIVE

Traditionally, transformers use mineral oil as the dielectric fluid, as it offers excellent insulating and cooling properties. However, as it is petroleum-based, disadvantages include potential flammability and non-biodegradability – significantly increasing risk. With a high calorific value and low fire point of 170°C, when mineral oil burns it releases a large amount of energy and heat that can quickly escalate into an uncontrollable blaze. As well as putting lives at risk, mineral oil can also prove hazardous to the environment, as its non-biodegradable and toxic properties can damage the surrounding ecosystem and aquatic life in the event of a fire or spill. The impact of such an incident can incur significant costs – both financially, in terms of lost income and litigation, and also at a cost to the company's public image. As such, there is a growing need to find a safer alternative to mineral oil – one that is environmentally friendly yet still has all the performance benefits for safe and effective power transmission and distribution.

Ester fluids are increasingly being specified by power utilities and end users, and adopted by transformer manufacturers, as they offer a fire-safe and biodegradable solution. Esters fall into two categories: synthetic and natural. Synthetic esters were first introduced in the 1970s to replace toxic Polychlorinated Biphenyls (PCBs) in existing transformers, in accordance with IEC 61099 and 61203 standards. From a technical and application perspective, synthetic esters are the product of choice. Natural esters were developed from sources such as soya bean or rapeseed oil to meet the need for more sustainable production using environmentally friendly raw materials.

As the shortcomings of ageing infrastructure have come to light, there has been a drive among insurance companies to take into account the adoption of more innovative dielectric fluids that reduce the risk to life and to property.

> Increasing numbers of insurers are recommending that their clients replace mineral oil with ester-based alternatives as the dielectric fluid of choice, both in terms of reducing risk and maintaining a strong corporate social responsibility policy.

RISKY BUSINESS

In order to protect against transformer failure and financial loss, a strategic asset management plan should be implemented, to ensure business continuity and minimal financial impact. One of the most important components in transmission systems, transformers play a significant role in the calculation of whole life costs. Analysing potential implications with the use of a risk matrix can help to define an effective asset management plan, outlining any risks to human safety, assessing the economic and environmental consequences, as well as managing the impact on reliability.

The growing need for reliable energy is driving the demand for insurance in the power and utilities sector, particularly as unplanned outages are becoming more of a threat. However, underwriting in this industry brings a unique set of challenges; companies are increasingly looking for cover from the planning stage through to construction and operation. Machinery breakdown cover and business interruption cover are becoming standard options too, ensuring companies don't suffer financially if production ceases following transformer damage. Environmental liability and directors' and officers' liability insurance (D&O) are also commonplace in this sector, with tailored risk consulting and property 'all risks' coverage a regular offering.

CONSIDERING ESTER FLUIDS

Faced with the task of convincing clients of the best measures to mitigate damage to power transformers, ester-based fluids present an attractive resource for insurers, offering a demonstrably safer alternative to mineral oil. The advantages include the following:

• Fire safety

Ester-based dielectric fluids offer transformer operators a fire safe option. Fire points (the lowest temperature at which the vapour of the fuel will burn for at least five seconds after ignition) are greater than 300°C for esters, making them K-class fluids as classified to IEC 61039. This figure is much higher than mineral oil, which has a fire point of only 170°C and an O classification, offering an inferior level of protection when compared to esters.

MIDEL transformer liquids have a 100 per cent fire safety record since the introduction of MIDEL 7131 synthetic ester in the 1970s. Given the scale of transformer fires and the fact that they are difficult to contain, ester fluids are becoming a key requirement for many power utilities, distribution networks and commercial/industrial facilities looking to minimise fire safety measures and reduce risk. Thanks to its fire safe properties, which allow fewer fire suppression systems to be used and, in turn, reduce space requirements, ester fluids are particularly well suited for use inside buildings and other critical areas – an advantage that mineral oil lacks.

According to FM Global's installation guide for transformers (datasheet 5-4, also referenced in standards such as IEC 61936), using fire-safe approved ester fluids also directly impacts installation considerations, leading to construction cost savings. Figure 1 demonstrates an example of an FM Global approved fluid in the volume range of 19,000 to 38,000 litres. With MIDEL fluid, transformers could be installed at this range – with only 1.5m between the bund edge and a building with non-combustible construction. This compares to the 7.6m of extra spacing required and the fire walls that need to be extended to 15.2m on either side of the bunded area with the use of mineral oil.

• Environmental protection

Using esters as the dielectric fluid in transformers can help to mitigate risks to the environment – making it a suitable choice for corporate social responsibility policies. Biodegradable, non-water hazardous and non-toxic, the chemistry of esters does not harm aquatic life if the transformer is damaged and causes the dielectric fluid to leak. All MIDEL fluids are readily biodegradable according to OECD 301, and fully biodegradable according to IEC 61039 – so that in the case of any leakage, costly claims can be avoided.

Figure 1: Two transformer installation comparison

Key

- Mineral oil transformer
- Ester transformer
- Containment
- 2-hour fire resistant barriers
- Area of substation

Notes

Transformers contain between 19,000 and 38,000 litres of fluid

Spacing based on FM Global datasheet 5-4 April 2016

Spacing based on fire clearances only

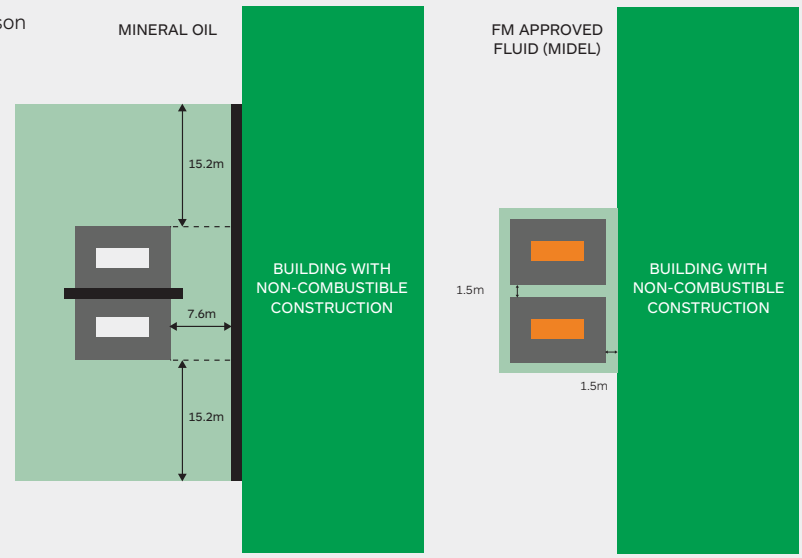
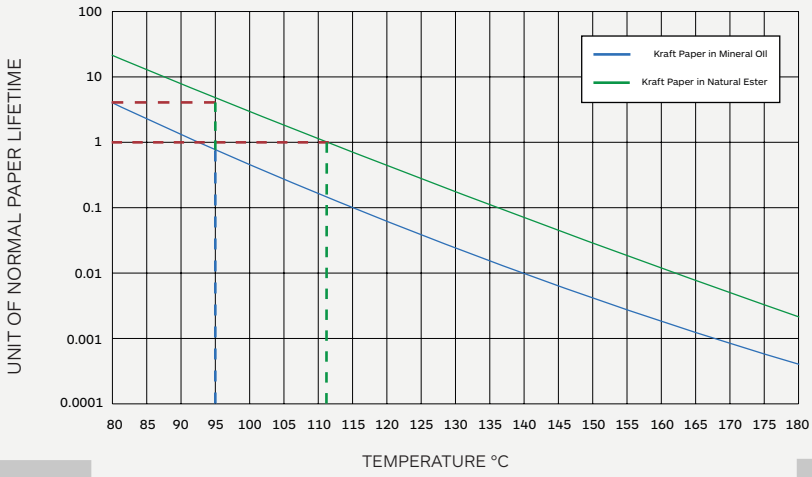
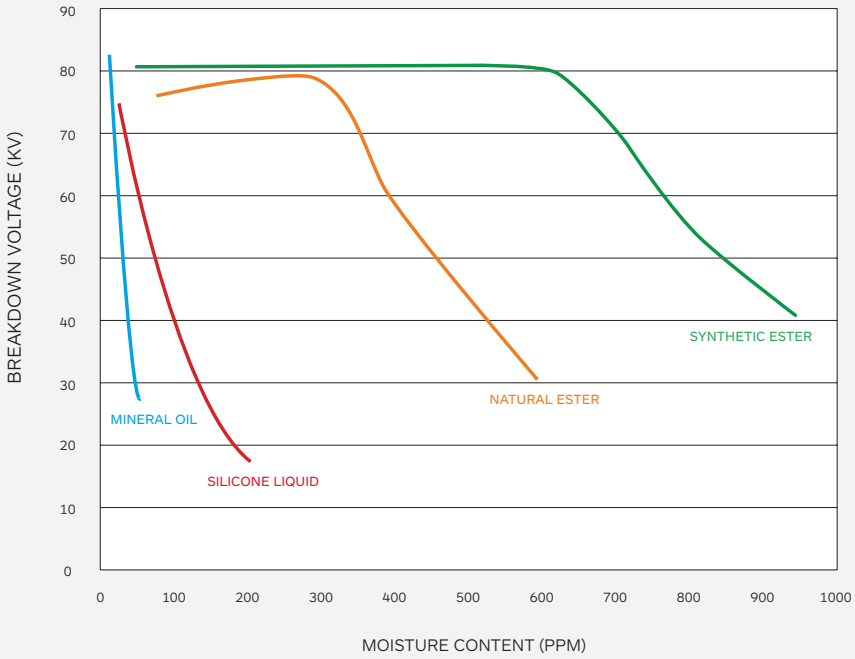


Figure 2: Impact of transformer operating temperature on insulation paper lifetime



Source: (IEC 60076-14 Annex C - (2013))

Figure 3: Breakdown voltage vs. moisture content at 20°C (IEC 60156 2.5mm)



• Moisture tolerance

Esters present a practical solution to moisture control in transformers. With a very high moisture tolerance, synthetic and natural esters can absorb more water than mineral oil, without compromising dielectric strength. In addition, when water interacts with esters, it slows the degradation rate of cellulose paper – as seen on Figure 2, highlighting the predicted lifetimes for kraft paper for both mineral oil and ester-based fluids. The advantage of this is two-fold: the extension of a transformer's operational lifetime or the opportunity for a transformer to be run at a higher temperature to increase the available power output from a given footprint.

COST

Financial justification is project and location dependant, with many new builds delivering real savings from reduced equipment or space requirements. Also, considering the asset's whole life cycle is key for clients looking to make changes in transformer design. While ester-based fluids are more expensive than mineral oils in the short-term, as part of a whole life costing plan, they can bring savings in the long-term. Despite often requiring a change in transformer design, replacing mineral oil with ester fluids can save costs through the removal of ancillary equipment, such as fire suppression systems or reductions in containment, and can result in a decrease in associated maintenance expenses. Plus, with a shorter installation time, transformers can be brought online faster, allowing for business continuity and minimal production downtime. Taking a conservative view of laboratory research also suggests that insulating paper within a transformer will have a 20-25 per cent longer lifespan if immersed in ester fluid, compared to mineral oil. Maintenance costs are therefore lowered, in turn reducing the overall cost of ownership and offsetting the initial capital expense.

RETROFILLING

To reduce the risk of claims and cost of insurance premiums, increasing numbers of insurers are advising their clients to undertake retrofilling on existing transformers. In effect, this involves replacing the mineral oil in transformers with ester fluids, in order to improve service life, reduce environmental impact and increase fire safety. Using MIDEL ester fluids for retrofilling of distribution transformers is a straightforward process; the thermal expansion characteristics, cooling performance and electrical properties are suitable for direct replacement of mineral oil. Due to its high moisture tolerance, another advantage of retrofilling is that it can replace mineral oils that have been adversely affected by high humidity levels. To highlight an example, in field trials with synthetic esters, transformers with extremely wet cellulose were brought back into operation by retrofilling.

INCREASED LOAD CAPABILITY

As part of an efficient asset management strategy, companies are looking at ways to increase transformer load as safely and as cost effectively as possible. Historically, this has been difficult with the use of mineral oils as there have been underlying safety concerns that come with increasing loads in transformers. With worries over pushing past the operational limit, design engineering of transformers was therefore more conservative as a result, to maximise safety. However, advanced electrical and thermal computer modelling means a clearer picture of transformer performance can be established at an early stage. Using ester fluids to increase safety has allowed existing transformers to increase loads, while maintaining the transformer footprint.

As the energy industry has evolved, there is a greater need for smaller transformers on trains and wind farms. In fact, using MIDEL fluids has led to the development of transformers that are up to 30 per cent smaller than traditional models. Today, insurers are keen to highlight the cost saving opportunities to their clients, both in terms of energy efficiency and the need for less equipment.

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CONCLUSION

Transformers present a significant challenge for asset maintenance managers, risk managers and insurers, particularly in view of growing energy demand in emerging economies. In developed countries, existing infrastructure needs to be maintained amidst increasing industry pressure to provide fire safe, environmentally friendly transformers for a wide range of voltages. The high-risk nature of the 'industry norm' mineral oils means that insurers are following risk mitigation strategies to advise their clients on the potential dangers of using this as a dielectric fluid – including safety, economic, reliability and environmental factors. Instead, companies are increasingly turning towards more robust, fire-safe and biodegradable ester-based dielectric fluids that maintain or improve performance levels. Increasing load levels in transformers also creates opportunities for the future energy mix, to meet the needs of evolving infrastructure such as small transformers on wind farms or windmills.

M&I Materials manufactures the MIDEL range of ester-based transformer fluids, helping to mitigate risks for critical power infrastructure and so minimise liability. As well as manufacturing ester fluids that can be retrofilled into both existing transformers and new installations, MIDEL also offers advice on how best to protect clients' assets, reducing the likelihood of claims.

References

[1] World Energy Outlook, OECD International Energy Agency
[2] Willis Tower Watson – https://www.willis.com/Documents/publications/Services/Property/Transformer_Problem.pdf
[3] FM Global – http://www.fmglobalreason.com/article/transformer-failure-ii
[4] FM Global – http://www.fmglobalreason.com/article/transformer-failure-ii

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