TRANSFORMERS: THE FUTURE

of Power Transmission and Distribution Needs

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THIS WHITEPAPER EXAMINES THE RISKS POSED BY INCREASING DEMAND FOR ELECTRICITY ON POWER AND TRANSMISSION NETWORKS, AND LOOKS AT HOW ESTER TRANSFORMER FLUIDS CAN HELP SAFEGUARD ASSETS IN URBAN ENVIRONMENTS INTO THE FUTURE.

INTRODUCTION

More people now live in cities than anywhere else. It is forecast that by 2050, almost 70 percent of the world's population will live in an urban environment[1], with many cities predicted to have in excess of 10 million residents. As urban populations grow, increased pressure is being put on existing – and often outdated – infrastructure, resulting in widespread resource strain and higher maintenance and operating costs. With population density increasing, initiatives to save space and improve safety are becoming more acute. The ability to gather data in real time is becoming a core element in how those challenges are being addressed; creating new systems that not only improve efficiency but also the quality of life for burgeoning city populations.

Referred to as smart cities, and built on the concept of the Internet of Things (IoT) – a network of technology and appliances that connect to, and function via, the internet – cities of this kind use digital data to understand how citizens live, work and move. The aim is to enhance wellbeing, optimise costs and reduce consumption of vital resources through connecting information on different amenities, such as power usage, transport, healthcare and waste. The outcome is an ability to provide immediate response to application and service challenges including equipment failure and maintenance issues, develop more sustainable and reliable communication processes and improve overall security.

The Department of Transportation in New York City, for example, has used real time information and advanced controls to regulate the traffic in Midtown Manhattan since 2010, while smart data modelling techniques analysed vehicle and pedestrian patterns. The result has been a 10 percent improvement in traffic travel times[2], and the removal of motor vehicles from some of the city's busiest roads, reducing pedestrian injuries by 35 percent[3].

It is predicted that by 2020 there will be 600 'smart cities', with a global market value of $400 billion. By 2025, they are expected to generate 60 percent of the world's GDP[4].

POWERING CITIES INTO THE FUTURE

The swift development of cities, combined with the growing number of people and businesses migrating to them, has meant a significant increase in the amount of energy required, to the point where demand is now overtaking distribution capability. Across the world, established cities are struggling to meet this demand due to the age and deteriorating condition of their networks and, without substantial investment, it is unlikely that they will be able to handle the increased energy needs of the future.

To reduce the risk of outages and maintain the high levels of power required by growing urban areas, governments across the globe have been investing in advanced grids that use a variety of measures to provide electricity in a sustainable and dependable way. Built to facilitate the integration of operational and energy processes, such as efficient and renewable energy resources, the grids gather information from components including advanced meters, appliances and renewable energy sources, and use it to understand and respond to changes in electrical demand in real time.

The result is the provision of reliable, available and efficient power, as well as lower management and operational costs, thanks to improved energy production and supply, and quicker restoration of networks after disturbances.

The cumulative spending on advanced grid technologies is predicted to reach $594 billion by 2023[5].

TRANSFORMERS IN GROWING CITIES

A transformer is a vital component of any power grid. Playing a key role in transmission and distribution, transformers are responsible for stepping electrical voltages up or down. For long-distance transmission of electricity, transformers increase the voltage generated by a power station in order to pass a low current through power lines, enabling efficient distribution over greater distances. However, as these voltages are not safe for use in buildings or houses, step down transformers are then used to reduce the voltage for everyday activity.

In terms of worldwide value, it is predicted that by 2022 the global transformer market will exceed $34.6 billion[6].

> The global power transformer market is expected to exceed 16,990 units by 2020, a significant increase from the estimated 11,352 units in 2013[7].

One critical element of a liquid-immersed transformer is its insulating fluid, which acts as a coolant to mitigate the risk of overheating as well as reduce electrical clearances. Traditionally, manufacturers have specified mineral oil for this purpose; its chemical characteristics are well known and it is available at an attractive price point for designers and buyers. However, with the growth in the number of applications transformers support – and corresponding rise in the number of installations in densely populated urban areas – the inherent weaknesses of mineral oil become all too apparent:

1. Mineral oil is highly flammable (igniting at around 170°C). When a transformer suffers a massive malfunction and ruptures, the mineral oil will empty out and create a dangerous pool fire. The potential for catastrophic damage to life and property is obvious; in June 2010 a transformer exploded in Old Dhaka, Bangladesh, resulting in 124 fatalities[8].

2. Mineral oil is non-biodegradable and toxic, presenting a serious hazard to aquatic life and surrounding ecosystems if spilled. Clean up processes are extremely expensive, lengthy and spell disaster for the offending company's public image.

3. Mineral oil is not moisture tolerant and becomes saturated with water at around 60 parts per million (ppm) at ambient temperature. As a result, both the transformer and insulating paper within it – which is most commonly damaged by water/moisture ingress – will experience a shorter shelf life compared with more advanced fluids.

In order to address these shortcomings, a safer alternative – ester based fluids – can be used. Fire safe, readily biodegradable, and with superior moisture tolerance, esters fall into two main categories: synthetic and natural. Synthetic esters, derived from raw materials, were first introduced in the 1970s to replace Polychlorinated Biphenyls (PCBs) in existing distribution transformers. Natural esters are obtained from renewable and natural sources, such as soya bean or rapeseed oil, and were introduced in the 1990s.

> Synthetic ester fluids are chemical compounds created through a reaction between alcohol and acids.

Between 2008 and 2013 alone, transformer damage cost FM Global clients a combined $339 million in lost revenue[9].

The unique properties of esters mean that they are well suited for transformers within areas of high population density, offering clear benefits in terms of space, safety and environmental stewardship.

INCREASED SAFETY

Ester fluids offer properties not found in other insulating fluids such as mineral oil, which allow for the safeguarding of citizens and the surrounding environment.

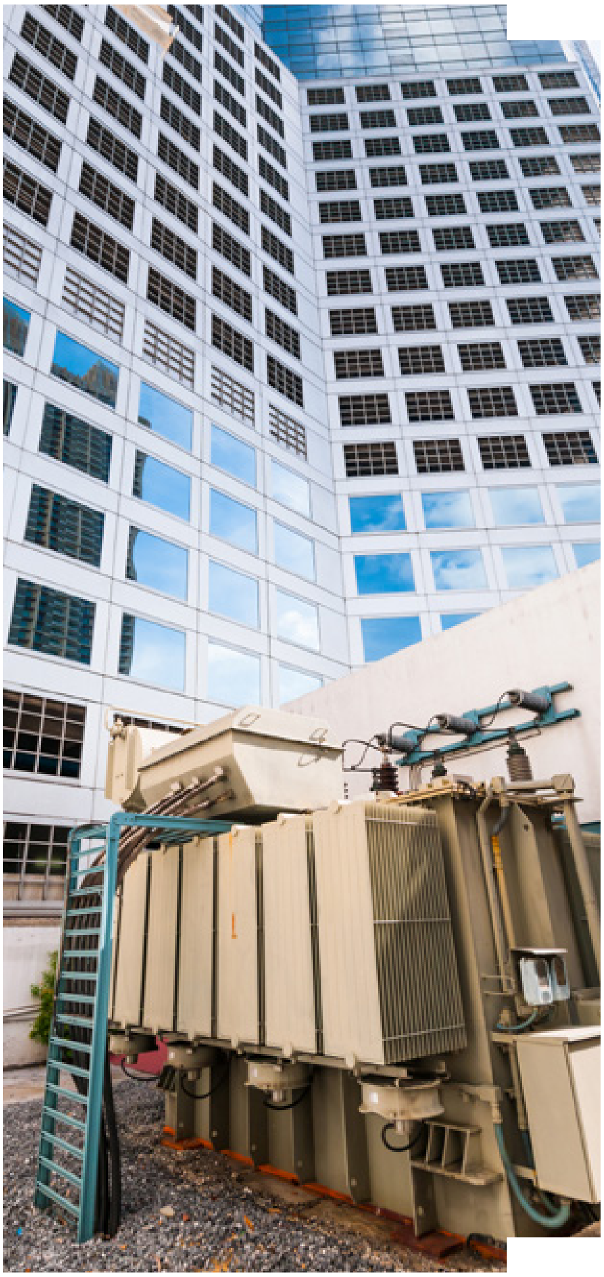
• Fire reduction

Ester fluids provide a fire safe alternative to mineral oil. With a fire point of over 300°C, compared to mineral oil at 170°C, esters have a higher margin of safety and, under typical circumstances, are also self-extinguishing. These properties mean they are ideal for use in transformers located in high-risk environments, such as built up urban areas, where they can improve the integrity of the surrounding infrastructure. In particular, MIDEL 7131 synthetic ester fluid has a 100 percent fire safety record since its first use in the 1970s.

• Environmentally friendly

Esters offer environmentally safe properties that are absent in conventional fluids such as mineral oil. As they are readily biodegradable and non-toxic, they present a far lower risk to the surrounding environment if leaked or spilled, and are also non-water hazardous, so less likely to pose a threat to aquatic life. The US Department of the Interior's Bureau of Reclamation states: "Ester based fluids have been determined to be non-toxic and biodegradable. Although clean-up is required, waste is not considered toxic. Mineral oil is considered toxic and non-biodegradable[10]."

An additional benefit of specifying ester fluids is the reduced need for containment surrounding the application, significantly decreasing the amount of real estate required.



"Developments and experience with ester-based insulating fluids show great promise for reducing the likelihood of transformer fires, and thus the need for suppression and containment while minimising environmental effects from the insulating medium[12]."

REDUCING OVERHEADS

Because of their fire safe properties, esters can also help utilities providers increase network efficiency and reduce overall expenditure:

• Space-saving potential

Unlike mineral oil transformers, which require up to 15.2m of surrounding fire walls, ester fluid transformers can be installed with no fire walls, only 1.5m away from a building with non-combustible construction[11]. The result is a considerable reduction in both civil construction and land costs. Ester transformers are increasingly being located underground in urban areas, with reduced fire protection, which delivers significant cost savings and improved aesthetics.

In addition, the high fire point of ester fluids means they can be run at higher temperatures, increasing the amount of power distributed without the need to expand the size and weight of the unit. This also permits original equipment manufacturers to develop smaller ester-based transformers that produce the same power output as larger mineral oil alternatives, further saving space.

• Lower total cost of ownership

Ester-based fluids can also help to reduce the cost of overheads through the removal of ancillary equipment such as fire suppression systems, reducing maintenance and allowing shorter cable runs due to decreases in construction footprint. This can ultimately help to reduce ongoing costs as well as capital expenditure. In addition, shorter installation times can help to bring transformers online faster.

Using esters has also been proven to significantly extend the life of cellulose insulation, due to their superior moisture tolerance, increasing asset lifetime by an average of 10 to 20 percent when compared with mineral oil.

• Protecting assets

If the performance of a mineral oil transformer becomes impaired, the oil can become saturated with small amounts of moisture, reducing its effectiveness and causing the transformer to fail. Because of ester fluids' superior moisture tolerance, they can absorb larger amounts than alternatives, without compromising their dielectric properties.

Laboratory studies show that synthetic esters maintain a high breakdown voltage of >75kV even when moisture levels exceed 600ppm (natural esters at this level can absorb 300 ppm). In comparison, even a small amount of water in mineral oil causes rapid deterioration in breakdown voltage.

Case study: Trials show that MIDEL 7131 can be used to bring transformers with very wet cellulose back into operation by a simple retrofilling procedure. One particular mineral oil filled distribution transformer was going to be de-commissioned due to high moisture levels; a retrofill with MIDEL 7131 brought it back to a state of safe operation, due to its ability to tolerate substantially larger amounts of moisture in comparison to mineral oil. More than five years later, the unit is still in perfect working order and has not required any further maintenance.

MEETING INCREASING ENERGY DEMANDS

As urban populations grow, it will be essential for an efficient and sustainable supply of electricity to be maintained across the grid. The high fire point of ester fluids also enables transformers to work at an overload of up to 20 percent, so applications can be run harder or for much longer, increasing the energy efficiency of the stock.

Furthermore, ester fluid transformers can be designed to capture excess heat, which can then be used for alternative purposes. This process is not possible with mineral oil, as its low fire point means that retaining any heat would be problematic.

INTEGRATING WITH EXISTING INFRASTRUCTURE

A key consideration in the development of future cities is whether new solutions can complement current infrastructures, without causing disturbances or power outages. One of the main benefits of using natural and synthetic esters is that they can be retrofitted into existing mineral oil transformers up to 33 kV/10 MVA (depending on asset condition), including sealed and free-breathing applications, without any modifications, allowing networks to be upgraded to meet the demands put upon them well into the future.

Case study: MIDEL ester fluids were used in an inner city transformer substation in Highbury, allowing electrical losses to be captured in the form of hot water. This ground breaking advancement enabled the power utilities provider to convert the losses into 1MW of power per annum. The resulting hot water was distributed to a local district heating scheme, supplying a nearby school and residential buildings.

[MIDEL®]
SAFETY INSIDE

CONCLUSION

Cities currently consume three quarters of the world's energy[13], a figure that is only going to increase in the coming years. The growing pressure on existing infrastructure means that steps must be taken to create safer, more sustainable electrical networks that can meet the needs of cities for years to come, without reducing safety margins. Specifying ester fluids within transformers allows advanced networks to be developed that can protect both people and the surrounding environment, cut expenditure on installation and maintenance, and increase transmission and distribution efficiency.

[1] World Urbanisation Prospects – UN DESA's Population Division, 2014
[2] The Mayor's Office of Technology and Innovation, New York
[3] India Smart Cities Challenge, Focus on New York
[4] McKinsey & Company data
[5] Navigant Research, Smart Grid Technologies
[6] Global Market Insights data
[7] Power Transformer Market Analysis by Product (100 MVA to 500 MVA, 501 MVA to 800 MVA, 801 MVA to 1200 MVA) and Segment Forecasts to 2020
[8] The Guardian, 2010
[9] FM Global
[10] US Department of the Interior's Bureau of Reclamation, Facilities Instructions, Standards and Techniques Volume 3-32
[11] FM Global datasheets 5-4 April 2016
[12] US Department of the Interior's Bureau of Reclamation, January 2005, Facilities Instructions, Standards and Techniques Volume 3-32
[13] Harriet Bulkeley, Cities and Climate Change, 2013

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