



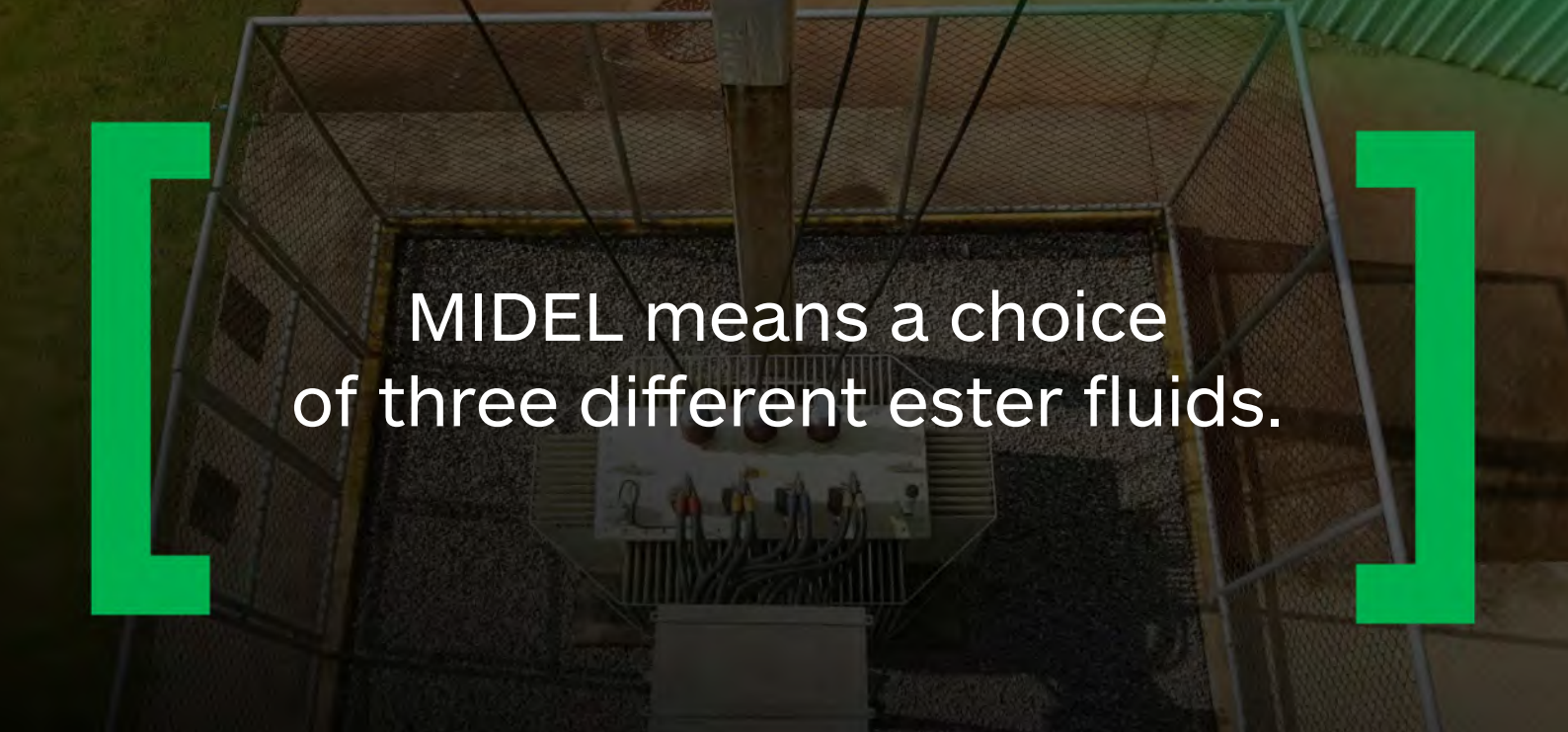
TRANSFORMER TECHNOLOGY^{MAG}

TRANSFORMER TECHNOLOGY^{MAG}

Better Solutions for a Changing World

Oils & Fluids

Interview with Peter Grolmus, CTO at EkoFluid GmbH: Driving Innovation in Transformer Oil Treatment
Oil as a Main Insulation Component in Liquid Filled Power Transformers: Quality and Consistency of Product
Technology Insights: The Essentials of Transformer Fluid Testing



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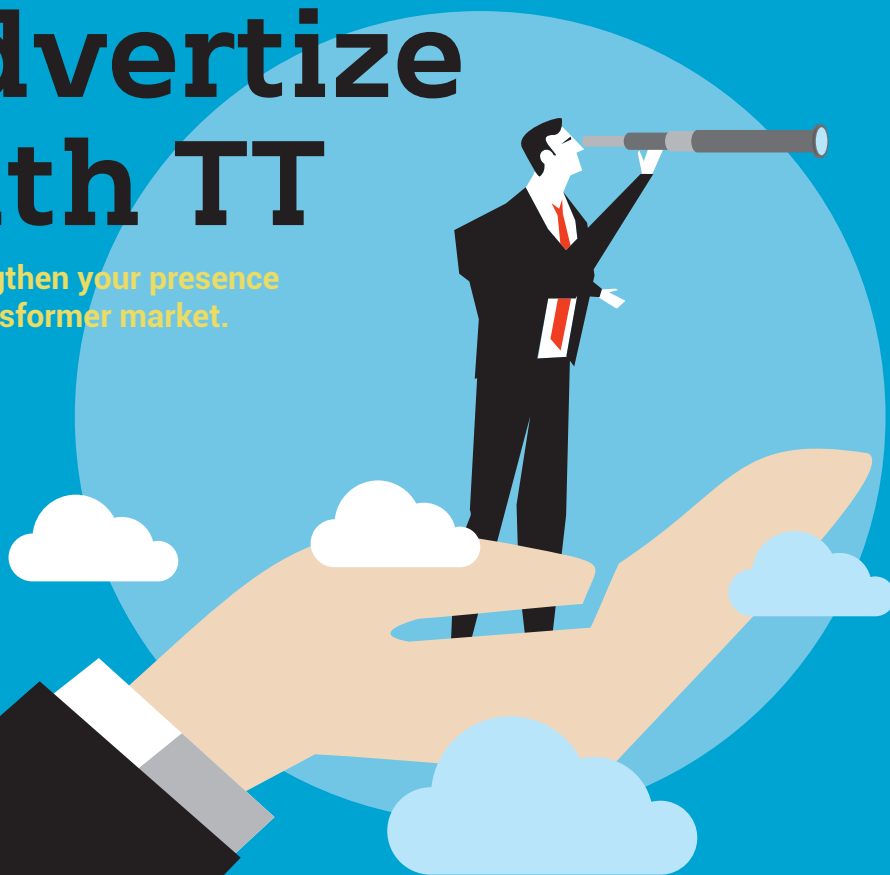
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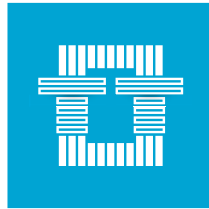
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Index

- Table of Contents_04
- Editors & Impressum_08
- Editor's Letter_10
- Events Watch_12
- Oil as a Main Insulation Component
in Liquid Filled Power Transformers:
Quality and Consistency of
Product_14
- Floating Solar Embraces Natural
Ester Transformers to Boost
Viability _20
- Connecting Transformer Monitoring
to Decision Making_28
- The Role of Ester Fluids in Fire Safe,
Greener, Better Performing Power
Networks_30
- Technology Insights by Corné
Dames: The Essentials of
Transformer Fluid Testing_36
- NYTRO® BIO 300X – The New
Bio-based Alternative from
Nynas_46
- Driving Innovation in Transformer Oil
Treatment: Interview with
Peter Grolmus, CTO at EkoFluid
GmbH _52

Table of Contents



14

Oil as a Main Insulation Component in Liquid Filled Power Transformers: Quality and Consistency of Product

Did you choose the correct oil for your transformer application? This is the one big question we are confronted with after reading through this outstanding article as a team of oil experts take us through a short history of oil testing from the late 19th century until today.

20

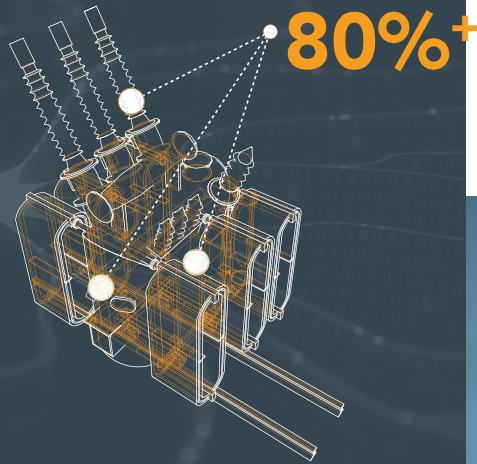
Floating Solar Embraces Natural Ester Transformers to Boost Viability

Floating photovoltaic is projected to grow at a rate of more than 20% in the next five years, and the use of natural ester in transformers has the tendency to become a new standard solution for these applications.



28

Connecting Transformer Monitoring to Decision Making



30

The Role of Ester Fluids in Fire Safe, Greener, Better Performing Power Networks

An Expert Q&A with Anthony Coker, Senior VP Sales & Commercial Operations MIDEL Americas, and Mark Lashbrook, Technical Director, M&I Materials Ltd

36

Technology Insights by Corné Dames: The Essentials of Transformer Fluid Testing



46

NYTRO® BIO 300X The New Bio-based Alternative from Nynas



52

Driving Innovation in Transformer Oil Treatment Interview with Peter Grolmus, CTO at EkoFluid GmbH





Index

Understanding the Importance of Advanced Transformer Oils **_60**

Transformer Oils Supply Chain in North America: Short and Long Term **_64**

Biotransol Transformers - Is the Environmental Sustainability a Right Way to Guide Technology? **_68**

Impact of US Elections on Global Energy Market **_72**

Axial Fans for Reliable Transformer Cooling **_80**

Traditional Transformer Oil vs. Today's Alternative Fluids **_84**

Managing the Reliability of an Industrial or Commercial Electrical Power System: Episode #6 **_90**

Contents

Table of

60

Understanding the Importance of Advanced Transformer Oils

An expert Q&A with Ed van Schaik, Product Application Specialist, Shell



64

Expert Opinion Transformer Oils Supply Chain in North America: Short and Long Term





68 Biotransol Transformers: Is the Environmental Sustainability a Right Way to Guide Technology?

72

Impact of US Elections on Global Energy Market

President-elect Joe Biden plans to take several big steps to reverse the decisions of the Trump administration, most notably rejoining the Paris Agreement. Climate change will be integrated into the country's foreign and national security policy, as well as trade as the U.S. focuses on renewable sources of energy and decarbonization goals.



84

Traditional Transformer Oil vs. Today's Alternative Fluids

Transformers have been filled with mineral oil since the late 19th century, but presently, alternative fluids are becoming more and more popular as we look for options that further prolong transformer life, lower environmental risks, and save money.

80

Axial Fans for Reliable Transformer Cooling

Cooling is of vital importance for increased service life and operational reliability of power transformers. Axial fans from Ziehl-Abegg have been used to efficiently and reliably cool transformers for over 50 years.



90

Managing the Reliability of an Industrial or Commercial Electrical Power System: Episode #6

In the last installment of his series, Chuck Baker lays out the ins and outs of the arc flash study, wrapping up his story of the Smith Factory.



Impressum

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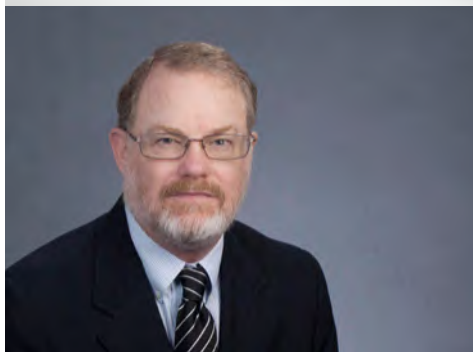
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Welcome to the future!



This, the third monthly Issue of Transformer Technology is as important and forward thinking as the last two, or should I say first two, monthly issues on Bushings. We had so much great content we had to break it into two issues: Part one and Part two. Now we move to an important and ever-changing theme: **“Oils & Fluids: Better Solutions for a Changing World”**.

Every week between our last issue and this digital issue, we featured an article from a transformer technology professional based on this important theme. And if you think these were limited to changes surrounding new fluids, natural and synthetic, you would be partially correct. While we wanted to make sure to update the TT Community on the advantages and benefits of natural and synthetic esters, we also wanted to address positive changes taking place with mineral oils. Our world demands changing approaches to current dilemmas and Transformer Technology is committed to bringing you the latest solutions.

And we also bring you great content on testing, maintenance and reliability features of existing fluids, ways you can use the fluid to address the health of your transformers. I am looking forward to advancing the Body of Knowledge in an area where we might think we know it all already. We don't!

The next few weeks you will also note the addition of several new features in the TT Community with the addition of the EPRA Corner, a particular passion of mine since I also serve as

the President of EPRA, the Electric Power Reliability Alliance. What we produce in EPRA, you will be able to access through the EPRA Corner. As an Alliance Member of EPRA, Transformer Technology has made it clear that they are committed to advancing the cause of electrical system reliability in the industrial and commercial markets.

And finally, one addition I am very proud of is **Tech Talk**, eight-to-ten-minute video talks with professional experts on specific problems and solutions relating to transformers. We know that video is an important way that people learn, especially the Next Generation, and given the industry-wide problem with losing so many “legacy leaders and professionals” to retirement, video is a great way for us to capture that legacy knowledge within our Body of Knowledge.

What started out as a simple magazine has become so much more; we are a professional community of transformer professionals and Tech Talks is another way we hope to serve our TT Community.

One last announcement! Given how we have moved the TT Community to an online, digital community supported by a monthly, curated magazine, the January/February issue will focus on the theme of: **Overheating, Cooling and Creative Solutions**. Under this theme there are an unlimited number of focus areas, such as, **Testing & Diagnostics, Gages, Radiators, Fluids, Fans, and Monitoring**.



I am looking forward to advancing the Body of Knowledge in an area where we might think we know it all already. We don't!

Do you have content to share, both editorial and advertorial? Let us know. For Editorial content let me know at alan.ross@transformer-technology.com or by phone at +1 404-992-5111.

Become a contributor. Change the world for a better future and become part of the professionals building the Body of Knowledge.

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It is time for a change.



Alan M Ross
CRL, CMRP
Editor in Chief
Transformer Technology



Alan M Ross



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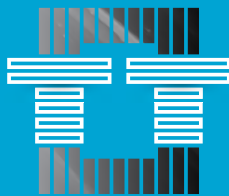


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Tech Talks



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Coming Soon

Oil as a Main Insulation Component in Liquid Filled Power Transformers

Quality and Consistency of Product

by **Lance Lewand**
Eileen Finnan
and **Melissa Zajac**



Lance R. Lewand received his Bachelor of Science degree from St. Mary's College of Maryland. He is actively involved in professional organizations including the American Chemical Society. He is a representative of the U.S. National Committee for TC10 of the International Electrotechnical Commission (IEC) and ISO TC28, ASTM D-27 since 1989, Chair of ASTM Committee D-27, sub-committee chair 06 on Chemical Tests, secretary of the Doble Committee on Insulating Materials, and a recipient of the ASTM Award of Merit for Committee D-27. Mr. Lewand is the Technical Director for the Doble Insulating Materials Laboratory. Since joining Doble in 1992, he has published over 75 technical papers pertaining to testing and sampling of electrical insulating materials and laboratory diagnostics.



Eileen Finnan is currently Director of Field Services, part of the Global Professional Services Group at Doble Engineering Company, providing operation management of field testing and remote services to clients. She also participates in cross-functional teams to deliver in-depth condition assessments of critical electrical assets and large-scale fleet assessment services. Her previous roles include Manager at Doble Engineering Material Laboratory which specializes in routine and specialized testing on insulating fluids from electric power equipment. Eileen received her Bachelor of Science degree in Physics and Chemistry from Trinity College in Dublin, Ireland.



Melissa Carmine-Zajac is Director of Laboratory Services for Doble Engineering Company. She has nearly 15 years of experience in chemical analysis, process engineering, and management of analytical laboratories. She is also an experienced Hazmat responder and industrial safety professional. Melissa is a member of the American Chemical Society, ASTM D-27 Technical Committee on Electrical Insulating Liquids and Gases, and is assistant secretary of the Doble Insulating Materials Committee.

FOR SOME, OIL IS AN AFTER-THOUGHT, JUST ANOTHER COMPONENT THAT COMES WITH THE TRANSFORMER. BUT OIL PLAYS A VITAL ROLE AS ONE OF TWO MAIN ELEMENTS OF THE INSULATION SYSTEM OF THE APPARATUS.

William Stanley's invention of the commercial transformer in 1886 and his subsequent AC electrification of Great Barrington, Massachusetts in that same year [1], pioneered the development of commercially viable electrical distribution systems. The first transformers were dry types using insulation made of cambric cloth and other cotton materials. In order to achieve higher voltages a better insulating medium was needed, and as early as 1887 [2] paraffinic mineral oil along with cotton-based materials were used to form the insulation system of early

transformers. Although plentiful, early paraffinic oils would often solidify near temperatures of 4°C or lower, causing retention of heat in the windings [3] that eventually led to failure. As a result, naphthenic oils with naturally occurring low pour points became the insulating oil of choice in the early 20th century – and is still the majority of what it is used today in most countries.



Oxidation of transformer mineral insulating oils occurs over time, at a rate that is dependent on the composition of the fluid and the conditions to which it is exposed while in service, such as temperature, oxygen and catalysts. Mineral oil filled transformers in the early 20th century were free breathing, which allowed a constant oxygen supply. Coupled with the poor refining practices of the time, which was a simple distillation cut of the crude that resulted in oils that were oxidatively unstable, the mineral oils in service tended to sludge and polymerize. This often resulted in solid terminal byproducts that had to be physically removed from the transformer with shovels. This caused operational headaches for utilities in that many transformer maintenance activities were engaged in to remediate oil issues.

As a result, there was a need to develop tests that could determine the quality and oxidative stability of the oil. In 1898, ASTM was formed as a forum to help industry leaders develop test methods for a variety of products including crude oil. ASTM committee D02 (then called committee N), founded in 1904 [4], was the first committee to take on the responsibility of establishing test methods for crude oil from which transformer mineral oil is refined. The very first methods did not come into existence until the decade between 1910 and 1920 and were limited to the evaluation of mostly physical characteristics; they did not address oil quality or oxidation stability. It wasn't until the 1940s through the 1960s that oil quality and oxidation

recognized early. In 1921, Dr. Van H. Manning authored a paper entitled "The Pioneer's Field in Petroleum Research". In that paper, Dr. Manning listed issues to be addressed in the petroleum industry, one of which was the prevention of oxidation of mineral oils in transformers [5].

In June 1923, the Massachusetts Institute of Technology (MIT) began a research study of the mechanism of the oxidation of mineral oils and of the action of negative catalysts (inhibitors) [6]. Inhibitors were known to bind with free radicals thus terminating the propagation process of oxidation. A year later in 1924, 177 substances were tested for anti-oxygenic protection of transformer oil, and 48 appeared to have inhibitory properties. Additional investigations were

a well-known factor that dictated the ability of the oil to dissipate heat from the windings and thus oils with lower viscosities became desirable. Corrosive sulfur was another issue of concern with oils at the time as it caused corrosion of the copper and silver components it was in contact with, leading to failure of the apparatus. Probably one of the most overlooked issues, which is still persistent today, is the interaction of the oil with the materials of construction of transformers, including gaskets, coatings, paints and other materials. The effects were a mutual problem with the oil causing the components to degrade, which resulted in leached material from the components contaminating the oil leading to compromised chemical, electrical and physical properties.



OIL SERVES AS AN IMPORTANT HEAT DISSIPATION MEDIUM HENCE THE MAKEUP OF THE OIL IS CRUCIAL TO PROPER AND SAFE OPERATION. POOR QUALITY OR IMPROPER APPLICATION CAN RESULT IN A HOST OF ISSUES, SUCH AS CORROSIVE SULFUR ATTACK OR GASKET INCOMPATIBILITY, MANY OF WHICH CAN RESULT IN FAILURE.

tests were established for use. In the 1950s, the ASTM D27 Committee on Insulating Fluids was established and split out of D02, and serves as the committee that produces standards for specifying, sampling and testing of insulating fluids.

Nevertheless, the problem of oxidation of transformer oils was

undertaken both in the United States and other parts of the world which identified other possible materials that could suppress oxidation [6]. Researchers in Russia [7,8], France [9] and England were embarking on a similar path at about the same time.

However, those were not the only issues to overcome. Viscosity was

For some, oil is an after-thought, just another component that comes with the transformer, but it plays a vital role as one of two main elements of the insulation system (the other being the cellulosic insulation) of the apparatus and it further serves as an important heat dissipation medium. Hence the makeup of the oil is crucial to proper and safe operation. Poor quality or

improper application can result in a host of issues, such as corrosive sulfur attack or gasket incompatibility, many of which can result in failure, and so it must be selected with care and diligence. And once selected, the oil needs to be monitored over the life of the apparatus, not only to ensure the oil quality is maintained so it can continue to serve its intended purpose, but also as a means of evaluating the operation of the transformer itself, through diagnostic tests such as dissolved gas-in-oil analysis (DGA), and the condition of the other main insulating component – paper, through such chemical markers in the oil as furanic compounds and alcohols.

As a result, standards were devised and published to ensure transformer oils meet certain minimum characteristics. These standards and

A good product and a consistently refined product are of ultimate importance. Evaluating oil to these published standards can help ensure such a product is selected. Detailed oil specifications should be part of new transformer specifications and the product delivered should be tested to verify specifications are indeed satisfied. Any purchase of oil should have the same specifications met to ensure only compatible products that meet standards are introduced into the transformer during its lifetime.

A good product provides the right mix of electrical characteristics required by the insulation system, the lack of corrosive sulfur (responsible for attacking the copper and silver in transformers and causing copper sulfide deposition in the paper),

oil-soluble compounds used as an indirect measure of the condition of the cellulosic insulation in a transformer. 2-furfural is the main compound used for diagnostic purposes, but it can also be used in refining of transformer oil during a solvent extraction process. If not properly removed prior to use, it may lead to an incorrect evaluation of the cellulose insulation as indications of overheated or aged paper insulation in a transformer. Specifications should also contain any other specific requirements. For example, applications such as cables, bushings and some transformers, may require the use of a negative gassing tendency oil.

For those that purchase transformers and other apparatus outside of their home country, knowledge of

PROBABLY ONE OF THE MOST OVERLOOKED ISSUES, WHICH IS STILL PERSISTENT TODAY, IS THE INTERACTION OF THE OIL WITH THE MATERIALS OF CONSTRUCTION OF TRANSFORMERS, INCLUDING GASKETS, COATINGS, PAINTS AND OTHER MATERIALS.

the tests that comprise them can be used to compare products and to evaluate the consistency of a product from year to year. One of the earliest specifications was the Canadian standard CSA-C50 [10] published in 1938, but it was not until 1961 that Doble Engineering company published a truly comprehensive standard called "Transformer Oil Purchase Specification (TOPs)" [11]. Other major specifications for new mineral insulating oils, ASTM D3487 [12] and IEC 60296 [13], were not published

good oxidation characteristics so the oil lasts the lifetime of the apparatus without sludging or degrading rapidly, and appropriate flow characteristic (as defined by pour point and viscosity) for operation in the intended climate and to meet heat dissipation needs. In addition, it is important to assess the actual chemical makeup of the oil as this has an impact on compatibility with other materials of construction in the transformer. For example, if a user decides to change out a high

international standards and products is very important. The apparatus will contain residual oil from factory testing or depending on the size, may come fully filled. Knowing which oil product was used along with the qualities of that oil is essential in making sure no unwanted oil characteristics are transferred over to the new electrical apparatus. For transformers, approximately 7% to 10% of the factory test oil remains in the apparatus when drained after factory testing is completed, and

DETAILED OIL SPECIFICATIONS SHOULD BE PART OF NEW TRANSFORMER SPECIFICATIONS AND THE PRODUCT DELIVERED SHOULD BE TESTED TO VERIFY SPECIFICATIONS ARE INDEED SATISFIED. ANY PURCHASE OF OIL SHOULD HAVE THE SAME SPECIFICATIONS MET TO ENSURE ONLY COMPATIBLE PRODUCTS THAT MEET STANDARDS ARE INTRODUCED INTO THE TRANSFORMER DURING ITS LIFETIME.

until the 1970s. All of these standards undergo regular revisions and are still published today and have many tests in common, but there are distinct and important differences. Thus, the user must be able to navigate these specifications, understand the significance of the tests, and decide which is most suitable for a given application.

aromatic oil with a low aromatic oil, the gaskets will contract, and leaks will develop which can be costly to remedy. Knowledge of additives is another important factor to consider and a good product should have nothing added that has not been mutually agreed on with provider and end user. Most modern specifications include a limit for furanic compounds,

if this retained oil is problematic, it can be enough to contaminate acceptable new oil used to fill the apparatus during commissioning. From 2001 to 2007, this very scenario played out and caused severe, to the point of failure, corrosive sulfur contamination in new apparatus around the world. In these cases, the original test oil used at the factory

OILS COME FROM DIFFERENT CRUDE SOURCES WHICH ARE PROCESSED USING A VARIETY OF REFINING METHODS, SO THE CHEMICAL MAKEUP OF THE END PRODUCTS WILL DIFFER EVEN THOUGH ALL MAY MEET THE SAME FUNCTIONAL SPECIFICATION. IDENTIFYING CHANGES IN DELIVERED PRODUCT IS EASIER WHEN ONE WITH CONSISTENT PROPERTIES IS USED.

was corrosive or in some cases was provided for commissioning on site as part of a turnkey project. These incidents highlight the importance of specifications containing test methods and limits that are rigorous enough to ensure suitable product is provided. Additionally, a detailed and comprehensive oil specification must be a part of the purchase process for transformers and updated on a regular basis.

Along with satisfying specifications, consistency of product should be considered. Oils come from different crude sources which are processed using a variety of refining methods, so the chemical makeup of the end products will differ even though all may meet the same functional specification. Identifying changes in delivered product is easier when one with consistent properties is used. It should also be noted that the chemical makeup of an oil can also impact gas formation under certain conditions; Dissolved Gas Analysis (DGA) is widely used as a diagnostic tool and knowing how an oil behaves in the equipment on a system from year to year can eliminate an unknown when diagnosing potential issues.

Specification testing of oil products can be undertaken periodically to monitor consistency. Oil surveys of transformer oils are available where oil products are compared year-to-year and results tracked. Doble Engineering Company has been performing such surveys either semi-annually or annually since 1953. In the early days, reports were specific for oxidation tests only, as that was the main issue at that time. Current testing is much more comprehensive with 30+ tests being incorporated and provides the user with a detailed analysis for each of the submitted oils. Oils are solicited from refiners around the world and then tested to Doble TOPS and ASTM D3487 specifications and the data along with the analysis of that data is then published. Utilities have used the report as the primary selection criteria of the oils to be considered for purchase.

In conclusion, insulating mineral oils should be selected on a quality basis, the ability to withstand oxidation, the characteristics which are needed and overall consistency of a product from year to year. Detailed oil and transformer specifications should be used to ensure suitable quality product is provided.

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Floating Solar Embraces Natural Ester Transformers to Boost Viability

by Alan Sbravati
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Alan Sbravati started his career working for a transformer manufacturer, mainly developing calculation and design tools for power transformers. After almost 9.5 years in the same company, he was the R&D manager for power transformers in Brazil and responsible for two global R&D projects directly related to transformer design and thermal calculation. After three years in a commercial role, he moved back to a more technical position at Cargill. Over the last six years he has been working with the development and application of alternative insulating liquids, especially natural ester fluid (Envirotemp™ FR3™), holding the position of Global Technical Manager since 2018. Alan chaired the Brazilian Standards Committee from 2012 to 2016, prior to moving to USA. He participates in IEC TC 14 and Cigre working groups. Currently he is a member of IEEE Transformers Committee, as chair of task forces and secretary of the Insulating Fluids Subcommittee.

Floating photovoltaic is projected to grow at a rate of more than 20% in the next five years, and the use of natural ester in transformers has the tendency to become a new standard solution for these applications.



As the world continues its quest to source more renewable energy, the latest frontier is adding solar fields above water. Installing solar fields on water provides new surface areas for power generation once only reserved for land use.

However, as the industry considers the added environmental risks and implications of integrating liquid immersed transformers into these installations, more-and-more are turning to natural ester units that not only mitigate the impacts in case of a spill in water contamination, but also deliver superior load capacity, longevity and lower costs.

Such floating solar projects are mostly taking advantage of water surface in areas which were not explored otherwise. The performance of the photovoltaic panels is favored by the cooling provided by the water and impacts on the environment are kept as low as possible. Floatovoltaics cost less to install than traditional land-based solar panels because there is no need to clear the land or treat the soil.

The solution avoids land expropriation, does not interfere with the existing ecosystem as much, especially when using lakes formed by the hydropower dams, and allows for using the same substations and transmission lines from the existing powerplant. As previously mentioned, covering the surface of one hydropower dam lake

would lead to peak generation that is 1.6 times higher than the power generated by the turbines of the power plant – so, at a fraction of the cost of the investment for a hydropower plant, its peak capacity could be more than doubled.

In fact, among the more than 60 countries pursuing the installation

of Floatovoltaics, 35 are home to an estimated 350 operational systems, which up until the end of August 2020 had a cumulative capacity of approximately 2.6 GW. Although still considered a niche, floating photovoltaic (FPV) is projected to grow at a rate of more than 20% in the next five years. And the use of natural ester in transformers has the tendency to



become a new standard solution for these applications.

Derived from 100 percent renewable plant sources, Cargill produces its FR3 dielectric fluid, which has already been used by several utilities and industrial customers as the dielectric fluid for their transformers for over 20 years. The fluid has also been seeing

significant growth as the industry brings more floating solar projects online. In 2020 alone, the global agricultural and bio-industrial firm has been involved in the first floating solar fields in Brazil, China and India.

In all these projects it was decided to use step-up transformers filled with Cargill's natural ester. This option also

suits the utilities that seek to minimize the risks and maximize the profits. As in any process involving a shift from a traditional solution that has been in use for over a hundred years to a new technology, the transition is being performed very carefully, as it should be. Transformers have a useful life expectation in the range of three decades or more, and the overall replacement ratio is estimated to be around 1% - 2% a year. So, gradually but continuously, the electrical system is being converted, one transformer at a time.

Making Waves in China

In China, from December 2019 to early 2020 a number of FR3 filled transformers for solar projects and retro-fill transformer projects were activated. Installations included 102 transformers of 35 kV 2000 kVA in the northeast province of Liaoning for State Power Investment Corporation Limited (SPIC); 30 units of 35 kV 3125 kVA for the floating solar project in the Hunan Province (mid-southern China) for China Guangdong Nuclear Power Group (CGN), and several retro-filled 10 kV 200-400 kVA transformers in Guangdong Province for China Southern Grid (CSG).

The CGN's floating solar project in Hunan Province is 100 MW. Considering 1,500 h/year of the equivalent full-loading cycles, the plant produces $100 \text{ MW} \times 1500 \text{ h} = 150,000 \text{ MWh}$ of electricity per year, or around 411 MWh per day. The investment in solar projects in China is about 4.5 CNY/W, or 661 USD/kW. Depending on the project type, some of the projects are backed by government allowance of approximately 0.18 CNY/kWh of electricity produced. However, as the solar industry in China develops and the market plays a bigger part, most projects do not have that allowance and investors are paying more and more attention to cost.

"The advantages of natural ester are already recognized in China," said Revin Wang, Cargill Technical Application Manager in China. "Furthermore, we can see important activities related to development

Since the beginning of its commercial use about 25 year ago, no pool fire has ever been reported in any FR3 filled transformer.



of national standards, such as the group of standards for natural ester filled transformers in general requirements, technical parameters, transformer assessment using dissolved gas analysis (DGA), operation and maintenance parameters and economic analysis guides in addition to the very relevant fire protection guide."

In addition, utilities like State Grid Corporation of China (SGCC) and China Southern Grid (CSG) have published corporate standards requiring their distribution transformer bids to be focused on natural ester filled units. In several provinces SGCC already started pilot bulk tenders for natural ester filled

distribution transformers. CSG is also working on a pilot project of a large natural ester filled power transformer at the voltage level of 220 kV and started an R&D project for 550 kV natural ester filled transformers.

These advancements are aligned with the government-led policy of green development that will leverage the adoption rate of natural esters, such as FR3 fluid, to become the main insulating liquid used in new transformers in China.

Getting Greener in Brazil

Companhia Hidro Elétrica do São Francisco (CHESF), a big Brazilian state company focused

on generation and transmission, installed the first floating solar plant on the reservoir of Sobradinho hydro power plant (UHE Sobradinho) in Brazil which was inaugurated on August 5, 2019.

This is a prominent hydro generation plant with a capacity of 1,050 MW and a large lake. The solar floating pilot project had the first stage done at the beginning of 2020, with an initial capacity of 1 MWp, but the total project may reach around 3-3.5 MWp.

It is a small plant, but a pioneer project in Brazil. At the same time, it avoids land consumption and allows for using the same



substations and transmission lines from the existing power plant, minimizing the implementation costs and environmental impacts. The transformer – a 4,200 kVA 34.5/2x0,36 kV filled with 2,500 liters of FR3 fluid – was supplied by WEG Brazil.

The floating solar power plant of CHESF is producing 1 MWp and has 3,792 solar panels occupying a total area of 11 km². This is the first phase of an R&D project that is planned to have a total of 2.5 MWp at a total cost of around \$10,000,000.

Utilizing the full potential of Sobradinho's water dam for installing photovoltaic panels would allow

for a peak generation 60% higher than the hydroelectric plant itself. Sobradinho dam has a surface area of 4,200 square kilometers, with a hydroelectric plant capable of generating 1,050 MW.

"Several utilities in Brazil are already purchasing new distribution transformers filled with natural ester," said Darcisio Sardagna, a Cargill commercial manager for the South America region. "The same trend is gradually being started in the large transmission companies, such as CHESF."

Many of these companies also have hydropower plants, which account for 63.8% of the electrical energy generation in Brazil [1], where the surfaces of the lakes formed by the dams could be explored. This reveals the potential of a major increase in the generation capacity with a minimum impact on the environment.

India Boosts Floating Solar to Meet Demand

Once an FR3 filled transformer is installed at a 100 MWp floating solar project in India, it will supply 50% of the country's natural ester requirement, with the balance achieved by the end of the year.

The collaboration between National Thermal Power Corporation (NTPC), a Delhi solar farm owner, Bharat Heavy Electricals Limited (BHEL) and Silchar Technologies Vadodara (OEM) is expected to be the largest floating solar installation in India, reaching 100 MWp in total. Once again, they chose FR3 fluid as the only insulating liquid for the transformers.

Several other floating solar projects are currently underway in India as the region acknowledges the advantages of using natural ester as the insulating liquid for



Photo: Cargill

all future transformers. Utilities and transformer manufacturers there have already been using FR3 in several projects, including transformers exported from India to other markets. The adoption curve is ramping up as more industry partners measure the results.

The Natural, Sustainable Choice

Beyond Brazil, China and India, countries around the world are realizing that natural ester's properties make it better for the Earth, compared to mineral oil and synthetic ester dielectric fluids.

Cargill's FR3 natural ester fluid is produced from 100 percent renewable vegetable sources, which gives utilities the option of using a dielectric fluid that not only dramatically minimizes environmental impact and health risks in case of a spill, but also performs even better than traditional alternatives.

Together with the environmental advantages, a strong motivation for the development of natural ester based insulating fluids was to enhance fire safety. As a "less flammable liquid" it has a very high fire point that effectively mitigates the risk of a pool fire being ignited. Since the beginning of its commercial use about 25 year ago, no pool fire has ever been reported in any FR3 filled transformer.

Natural ester fluid continuously wicks away moisture from the solid insulation, increasing the reliability and resilience of transformers and, thus, of the grid.

Aligning Next-Gen Solutions with Proven Partners

For decades Cargill has been reliably selecting, modifying and reacting various plant-based chemistries to create specific, innovative solutions for our industrial customers, including insulating liquids, road construction products and even the biobased plastics.

As manufacturers across industries look for smarter ways to formulate their products to improve performance and gain total cost efficiencies, Cargill's broad and diverse portfolio of products and services help create solutions to help customers increase performance and lower costs in a responsible, sustainable manner.

The case of floating solar generation is one more example of successful cases of dielectric fluid application. The dielectric insulating fluids

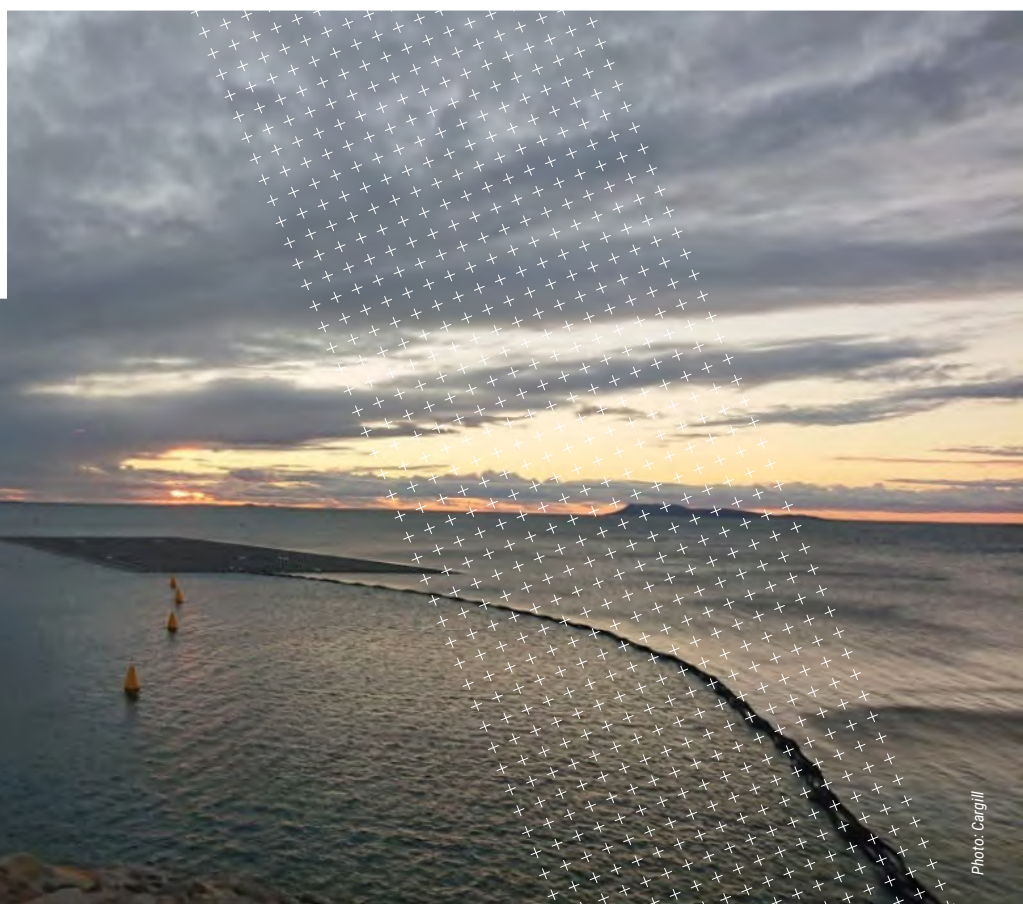
produced and commercialized by Cargill are already in use in over 2.5 million transformers for more than 20 years around the globe. It has a special synergy with renewable energy generation projects since it also uses renewable resources (98% bio-based), is readily biodegradable and proven to be non-toxic in acute water and oral toxicity tests.

Cargill has been actively approached by utilities around the globe to present the advantages of using natural ester in their transformers for years. The application in the transformers used for renewable energy generation is unique for the global business as it actively works with companies developing and operating new generation grid technology.

As a high-performance alternative for the traditional mineral oil used in transformers, natural ester fluid continues to be positioned as the fluid of choice for floating solar projects. Utilities face competing demands to be profitable while providing reliable, safe and consistent power to communities, and using an increasing percentage of renewable energy sources.

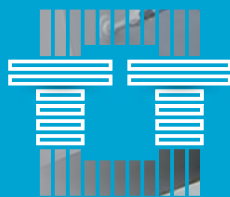
Reference

- [1] Government of Brazil, accessed at <https://www.gov.br/pt-br/noticias/energia-minerais-e-combustiveis/2020/01/fontes-de-energia-renovaveis-representam-83-da-matriz-eletrica-brasileira>



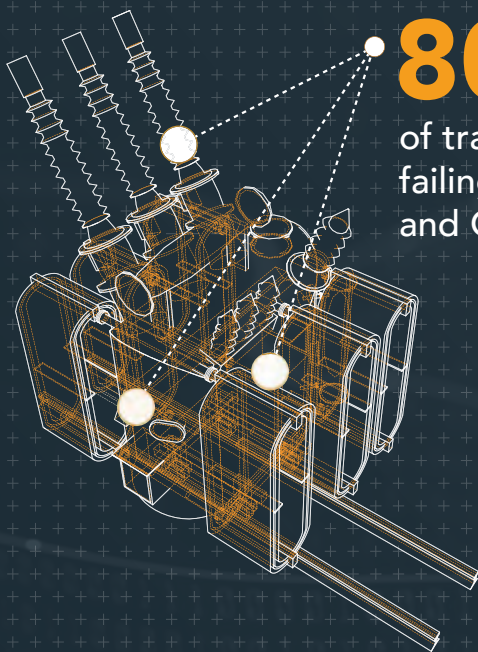
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80%+

of transformer failures are due to failings in the Bushings, Windings and OLTCs.

WHY IS DGA NOT ENOUGH?

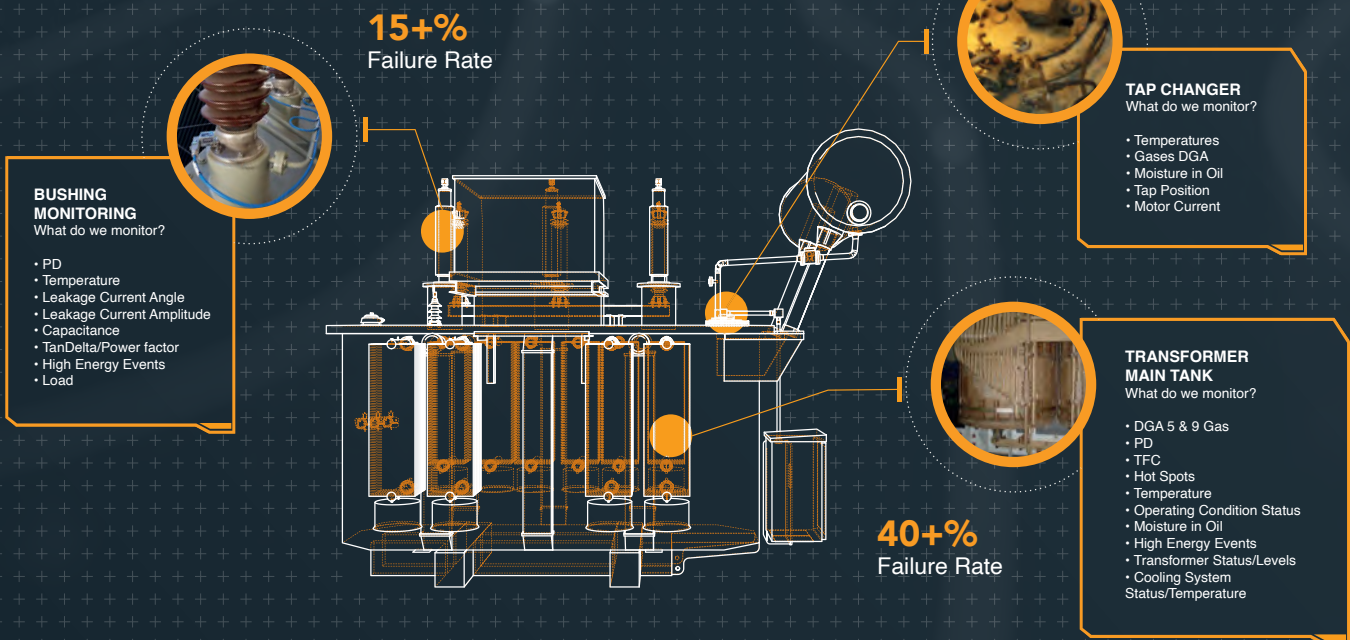
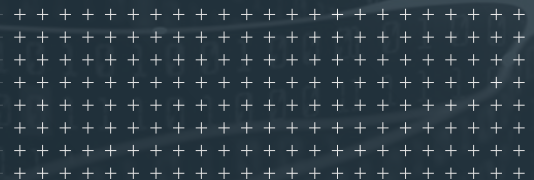
Only by monitoring all components on the transformer can an accurate picture of transformer health be determined. The key benefit of online monitoring is the ability to detect anomalies under real operating conditions that otherwise would not be detected and then follow up with the best course of action.

WHY TOTAL TRANSFORMER MONITORING?

Build a complete picture of transformer health with TOTUS Transformer Monitoring. Integrating DGA, Partial Discharge (PD), Bushing Monitoring (BM), Through Fault Currents (TFC) and Transformer Analytics into a single system, TOTUS delivers an in-depth understanding of transformer health.

The benefit to utilities:

- Significantly **reduced risk** of sudden transformer failure and associated costs
- Enhanced **predictive maintenance** to extend life of the transformer
- Uninterrupted power supply, reducing unplanned outages



CIGRE TB642



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POWER

CONNECTING DATA TO DECISIONS

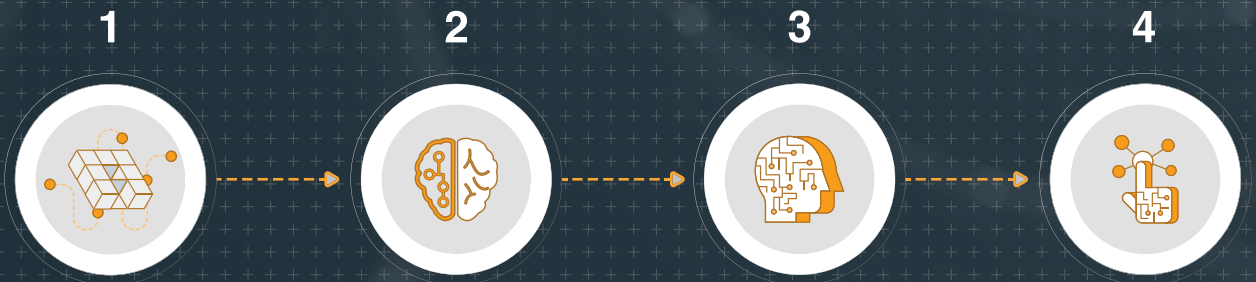
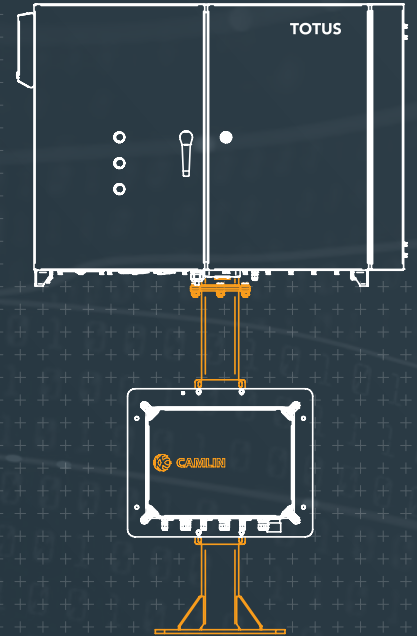
CONNECTING TRANSFORMER MONITORING TO DECISION MAKING

Our priority is optimising the health of your transformer fleet, letting you stay focused on what you do best — keeping the lights on.

We understand the increasing challenges facing the global power industry. Ageing assets are being driven to work harder as the network evolves, while asset managers are constrained by limited resources and reduced maintenance budgets.

Data and insights are therefore key to driving business critical decisions about assets. At Camlin we deliver that data through our TOTUS monitoring solution. We work with you to interpret this data and deliver insights that drive action. Our goal is to 'connect the dots', linking complex data sets with actionable information. This provides the complete picture you need to make informed decisions and optimise long-term transformer health.

TOTUS



1

2

3

4

GENERATE THE DATA

Detect anomalies under real operating conditions, triggering an alarm

TRANSFORM DATA TO INFORMATION

Correlate anomalies to determine risk, condition & failure mode

APPLY KNOWLEDGE

Contextualise information, combine with offline data to trigger correct offline test and confirm failure mode

PRESCRIBE ACTION

Armed with detailed data and insight, determine best course of action

Q&A

THE ROLE OF ESTER FLUIDS **IN FIRE SAFE, GREENER, BETTER PERFORMING POWER NETWORKS**

M&I Materials combines a long pedigree of established, proven products with a robust research and development ethos aimed at bringing new solutions to market.



Transformer Technology: First tell me about the company itself, its history and background.

Anthony Coker: To put it in context, MIDEL is one of a portfolio of brands owned by M&I Materials, an independent, privately owned British company whose roots can be traced back to 1901. M&I Materials exports to 60+ countries around the globe from our Manchester, UK base and we have an expanding network of international offices and production facilities across the Americas, Africa, Middle East, Europe and Asia Pacific.

Our combination of manufacturing, sales, marketing and technical expertise, combined with our global partnerships with leading universities and research facilities, enables us to help make tomorrow's innovations possible by commercializing materials for demanding applications. The company grew out of a division of GEC Alstom and was established in 1993 as a result of a management buy-out. M&I Materials combines a long pedigree of established, proven products with a robust research and development ethos aimed at bringing new solutions to market.

The company has been producing MIDEL ester transformer fluids since the 1970s, and now manufactures MIDEL in the USA and South Africa in addition to its UK operations. MIDEL is now seen as the world's leading brand of ester-based dielectric fluids and is chosen by utilities and transformer manufacturers worldwide because of its excellent track record and ability to effectively mitigate risk.

As it relates to ester fluids, tell me about MIDEL's initial roll-out as a replacement for PCBs in the 1970s, which were predominant in transformers at that time?

Mark Lashbrook: You're right, the drive to replace Polychlorinated Biphenyls (PCBs) in fire safe transformers was a key driver for the launch of MIDEL, which was patented and first deployed in the late 1970s, actually to refill a transformer in a British Steel facility. Plainly, the toxicity issues related to PCBs meant the industry was looking for a dielectric fluid that was safer to handle. MIDEL delivered that solution, in addition to the further benefits of fire safety, biodegradability and moisture tolerance.

AC: Just touching on that point, I see the market really starting to get the business case for ester transformer fluids. I think it's now accepted that in addition to the benefits Mark identified, MIDEL offers tangible advantages in terms of cost reductions, total cost of ownership and even Environmental, Social, and Corporate Governance (ESG) credentials.

What is the difference between Synthetic and Natural Esters? Is biodegradability the same for synthetic and natural ester fluids?

ML: To be clear, while mineral oil is a good dielectric liquid, it's neither a K class (high fire point) liquid nor is it readily biodegradable. Synthetic esters emerged in the 1970s, followed by natural esters in the 1990s to provide fire safe K class compliance and readily biodegradable status along with superior sustainability.

A synthetic ester is made from carefully selected acids and alcohols. In MIDEL 7131, there are no double bonds in the R chains between carbons (saturated bonds) which increases its oxidation resistance and thermal stability. While being a synthetic fluid, MIDEL 7131 is nevertheless readily/fully biodegradable and fire-safe. It's the premier ester transformer fluid, approved and certified by FM® and UL® - as are MIDEL natural ester fluids.

AC: On the other hand, natural ester dielectrics are produced from vegetable oils, sourced from readily available plant crops. The structure of natural esters is based on a glycerol backbone, to which is bonded 3 naturally occurring fatty acids. In the MIDEL range, there are two natural ester fluids, namely MIDEL eN 1215 (soybean) and MIDEL eN 1204 (canola/rapeseed). The properties of the natural ester, as a transformer dielectric liquid, are affected by the base vegetable oil used to make it, and this affects the oxidation stability of the natural ester as well as its cold temperature pour point. Our technical position is that all natural esters should only be used in sealed systems where there would be no direct exposure to atmospheric air for elongated periods of time.

Responses from:



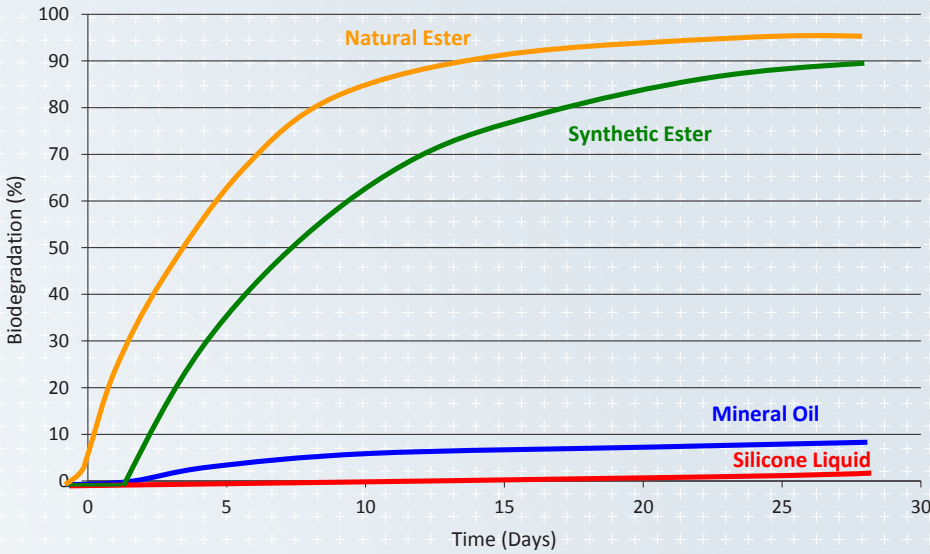
Anthony Coker
Senior VP Sales & Commercial
Operations, MIDEL Americas



Mark Lashbrook
Technical Director, M&I Materials Ltd

Ester transformer fluids are now an integral part of the mainstream electrical infrastructure, and that role is only going to expand as more and more forward-thinking OEMs and utilities look to capitalize on the tangible benefits offered by MIDEL ester fluids.

In terms of biodegradability, all MIDEL fluids are fully/readily biodegradable. It's a point more easily explained with this illustration:



Cigré brochure 436, Experience in Service with New Insulating Liquids, 2010

ML: And another key difference between synthetic and natural esters is the pour point temperature. This table helps to illustrate the differences:

	MIDEL 7131 (Synthetic)	MIDEL eN 1204 (Canola)	MIDEL eN 1215 (Soybean)
Pour point	-56°C	-31°C	-18°C

You'll see that MIDEL 7131 is an ideal choice of fluid for transformers placed in cold climates to -56°C. MIDEL eN 1204 operates in temperatures as low as -31°C, and soybean-based MIDEL eN 1215 has a pour point of -18°C. These different pour points, along with an assessment of the low temperature viscosity, can help transformer OEMs and end users choose the ester fluid that will work best given the transformer's ultimate location and operating environment.

The practice of retrofilling mineral oil filled transformers is becoming more common in the US and Canada. Can you tell us how the rest of the world is handling this situation and how MIDEL is involved?

ML: Retrofilling has a long history in Europe, with large projects dating back to the 1990s and is rapidly gaining traction across the rest of the world. We are assisting utilities and other end users in retrofilling projects in the Americas and across Asia-Pacific. The initial key driver is usually a requirement for increased fire safety in an existing transformer, however the ancillary benefits of environmental protection and solid insulation protection are also acknowledged.

AC: A key consideration in asset management, especially when dealing with ageing infrastructure, is whether new solutions can complement existing substations without causing disturbances or power outages. A key benefit of our natural and synthetic esters is they can be retrofilled into existing mineral oil transformers up to 66 kV (69 kV in the Americas), including sealed and free-breathing applications without the unit needing any modifications other than new gaskets and seals. Higher voltage level transformers can be retrofilled; however, the designs would have to be investigated thoroughly for candidacy. Retrofilling is a proven solution that can be performed in situ, allowing networks to upgrade without the end user incurring Capex cost. We have many examples where retrofills were done overnight at commercial sites, with no impact on operations.

While being a synthetic fluid, MIDEL 7131 is nevertheless readily/fully biodegradable and fire-safe. It's the premier ester transformer fluid, approved and certified by FM® and UL®- as are MIDEL natural ester fluids.



[MIDEL®]
SAFETY INSIDE

There is a growing use of ester fluids in bushings. How is MIDEL involved in this area and where do you see it moving/growing in the future?

ML: MIDEL 7131 has been utilized in the world's first range of high voltage oil filled bushings from Trench. These are a major step forward in technology, allowing users to specify a fire safe ester bushing to accompany their ester filled transformer. We expect to see more developments of this type of technology in the near future and work through our research programs to support this type of innovation.

Regarding increasing urbanization and the rapid growth of cities. What do you see as the role for ester transformer fluids, both natural and synthetic, as an element of risk mitigation?

AC: There's no doubt in the Americas and globally, we are seeing a large urban population growth. City centers, pre-pandemic, are abuzz with construction of mixed use complexes that really pack in the space and the people. With that comes increased pressure on existing – and often ageing – infrastructure, resulting in widespread resource strain and higher maintenance and operating costs. With population density increasing, initiatives to save space and improve safety are now actively pursued. That's where MIDEL is making a real difference in urban substations. Densely populated areas need increased fire protection; MIDEL fluids deliver that protection with a fire point of over 300°C (compared to mineral oil at 170°C). And for some cities, the green attributes are more than just a bonus benefit as they help them address environmental issues and meet their sustainability goals.

Earlier I mentioned the business case for using esters, and here's where it gets really interesting: Esters can also help utilities providers increase network efficiency and reduce overall expenditure. How? Let's look at reducing the substation's footprint. Unlike mineral oil transformers, which require up to 15.2m of distance to the surrounding fire walls, ester fluid transformers can be installed with no fire walls, only 1.5m away from a building (with non-combustible construction). The result is a considerable reduction in both civil construction and land costs. In addition, ester transformers are increasingly being located underground and under buildings in urban areas, delivering significant cost savings and improved aesthetics.

Then there's the question of total cost of ownership. Ester-based fluids can also help to reduce overhead costs through the removal of ancillary equipment such as fire suppression systems, reduction in maintenance and allowing for shorter cable runs due to a smaller construction footprint. This can ultimately help to reduce ongoing costs as well as capital expenditure. Also, less complexity in construction helps bring substations online faster.

ML: There's an important technical aspect to point out here: Mineral oil transformers can become saturated with small amounts of moisture, coming from the external environment or ageing of cellulose insulation, reducing its effectiveness and potentially causing the transformer to fail. Because of ester fluids' superior moisture tolerance, they can absorb larger amounts of that water, without compromising their dielectric properties. The uptake of water from ageing paper by the ester can also significantly extend the life of cellulose insulation, increasing asset lifetime by an estimated 20 percent when compared with mineral oil.

How exactly does ester fluid make it possible to manufacture a smaller transformer?

ML: 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 transformer unit. This also permits OEMs to develop smaller ester-based transformers that produce the same power output as larger mineral oil alternatives, further saving space. This characteristic makes MIDEL ester fluid an ideal component of mobile resilience transformers, when you consider that a lighter transformer with reduced dimensions will be easier to transport around a city or region than a bigger, heavier mineral oil version.



A key benefit of our natural and synthetic esters is that they can be retrofilled into existing mineral oil transformers up to 66 kV, including sealed and free-breathing applications, without the unit needing any modifications other than new gaskets and seals.

Your opinions on the future of ester fluids in the power sector?

AC: As urban populations grow, not only in the Americas but worldwide, the power sector will be challenged with guaranteeing an efficient, safe and sustainable supply of electricity across the grid. Just within the last two months, two utilities, one in the USA and one in Canada, experienced large transformer fires and they happened to be sited next to key waterways. Toxic firefighting chemicals and a deluge of water along with some of the mineral oil made their way into the rivers which are used downstream for municipal drinking water. But the high fire point of ester fluids is only one of the ways to enable transformers to be "sweated" safely. Couple that with the ability to work at an overload of up to 20 percent, and you have assets that can be run harder or for much longer, increasing the efficiency of the fleet.

And here's a new one: ester fluid power transformers can be designed to allow excess heat capture, which is then used for alternative purposes. Think of it as co-gen in a way and this process is not possible with mineral oil, as its low fire point means that retaining any heat would be problematic. For example, I recently toured a new, large inner-city substation in London where MIDEL ester fluids allowed electrical heat losses to be captured to heat water. The resulting hot water was distributed to a local district heating scheme, supplying a nearby school and residential buildings. This groundbreaking advancement enabled the power utility to convert the losses into 1 MW of power per annum and the three transformers involved are rated at 420 kV each.

The bottom line is this: specifying ester fluids in 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. Additionally, in many cases where the design includes the benefits we discussed here, the overall lifetime cost of the installation is much lower.

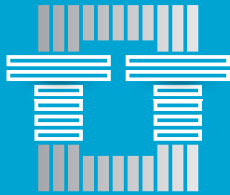
The drive for safer, greener, better performing transformers and substations is now a mandate for power sector planning. I see a clear direction of travel – ester transformer fluids are now an integral part of the mainstream electrical infrastructure, and that role is only going to expand as more and more forward-thinking OEMs and utilities look to capitalize on the tangible benefits offered by MIDEL ester fluids.



MIDEL is now seen as the world's leading brand of ester-based dielectric fluids and is chosen by utilities and transformer manufacturers worldwide because of its excellent track record and ability to effectively mitigate risk.



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Corné Dames is the Managing Director of Independent Transformer Consultants, always striving to keep on top of new developments and research. She has expertise as Laboratory Manager in the analysis of transformer oils and as diagnostician identifying problem areas in transformers, as well as profiling of transformers according to available results thus empowering the customer to take preventative steps in maintenance. Corné has vast practical and theoretical knowledge on reliability maintenance programs. Coming from a strong chemical background she has insight in all the chemical processes that are part of the transformer system. Coupled with technical insight, her knowledge and experience help customers optimize their reliability maintenance and electrical asset lifetime.

**Dissolved gas analysis (DGA)
has been a powerful tool for industry
to detect and identify faults
in oil filled transformers.**



Introduction

This article will be looking at the differences in analytical and diagnostic condition monitoring tools and fault identification techniques for transformers filled with natural and synthetic ester fluids in relation to the known mineral oil filled units. A reliable condition monitoring system for transformers, both distribution and power transformers, is of the utmost importance to ensure electrical reticulation system reliability.

In this article, we will focus on the chemical-based techniques for condition monitoring available in the industry.

We will look at the analytical tools for determination of moisture content, viscosity, acidity, DGA and furan content.



Moisture Analysis

According to IEC Std. 60814 we will apply the standard procedure for Karl Fischer Titration (KFT). An equilibrium chart is available for mineral oil that indicates the moisture content in paper (%) according to the result acquired by the KFT analysis. With this chart, the analyst can establish the approximate moisture content of the paper according to the actual KFT result and the temperature of the oil at sampling, which is due to an established equilibrium equation for this phenomenon. Ester fluids have a higher moisture solubility than typical mineral oil, and we cannot use the equilibrium conditions as set for mineral oils. As the polarity of natural ester fluids is higher than that of mineral oils, these fluids will admit higher amounts of water in solution before reaching saturation level

It should be noted that operating transformers experience dynamic temperature variations, therefore, moisture equilibrium conditions in transformers are hardly ever achieved – this is even more true for ester fluids as these display a higher viscosity.

Dissolved Gas Analysis

Dissolved gas analysis (DGA) has been a powerful tool for industry to detect and identify faults in oil filled transformers.

The objectives of DGA are a) to check that equipment is in a good condition, b) to monitor operating conditions of a transformer, and c) to prevent failure and their possible localization. DGA has mainly been used for transformers filled with mineral oil. Since the request for a more environmentally friendly, less flammable liquid to be used in transformers, a lot of research has gone into synthetic and natural ester fluids analysis. The research is done to determine if these types of fluids would be beneficial to the industry and the equipment they are purposed for. Ester fluids have been introduced to the transformer

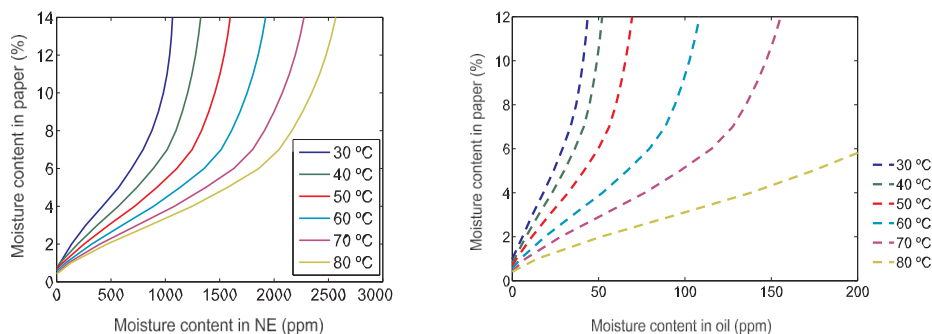


Figure 1. Moisture content in oil (mg/kg): natural esters (left) and mineral oil (right) [1]

	Moisture content (ppm)					
	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C
Mineral oil	38	58	80	119	171	228
Natural ester	575	699	837	1001	1182	1330

Table 1. Moisture content of the two insulating fluids at RH 50% and variable temperature

sector and are currently used in distribution transformers, bushings and tap-changers regardless of some limitations, such as higher cost, required protection from oil oxidation, very-low temperature operation, and full clean-up required by most national and regulatory bodies in case of a spill.

The chemical structure of esters or silicone fluids cannot be directly correlated to that of mineral oil as their chemical molecule construction is entirely different. The gassing of an insulating liquid under electrical discharge depends on the chemical composition of the fluid, electrical field stress, temperature, and time. The gassing tendency of natural esters is much lower than that of synthetic esters and mineral oils. This is most likely due to the amount of unsaturated, non-aromatic molecules as compared to mineral oils [2].

To ensure that the same level of monitoring is available to customers using ester fluids in distribution transformers, bushings or tap-changers, a group of industry leaders came together to set the guidelines and standards for analysis of ester fluids. The findings and recommendation have been published

in Technical brochure D1/A2 – Advance in DGA interpretation [3]. This document addressed the need for diagnostic tools to clearly identify electrical and thermal stress conditions in operational equipment including transformers, bushings, and on-load tap-changers. The application of non-mineral fluids in power transformers poses a challenge as higher electrical and thermal stresses are inevitable, and a higher level of DGA monitoring would be required. More frequent DGA analysis in collaboration with on-line monitoring of gas formation are required. To ensure that the diagnostics are perfectly accurate and that the recommendations according to the oil analysis will give the true picture of the state of the equipment, interpretation of the key gas concentrations as well as ratios and what abnormalities this may indicate is of the utmost importance. This will ensure that any corrective actions recommended by the diagnostics will ensure reliability, accurate maintenance decisions and optimized lifetime for the equipment in question.

We will look at these standards and guidelines and compare them to the standard procedures and guidelines for mineral oils, pointing out some differences and similarities.



Application of DGA to Non-Mineral Fluids

Non-mineral fluids like natural esters, synthetic ester and silicone fluids are used increasingly due to their environmental friendliness (ester fluids) and low fire hazard.

It should be noted that analysts should ensure that they calibrate with gas-in-oil standards specifically for non-mineral oils as the partition coefficients are significantly different for mineral and non-mineral oils – this is for headspace extraction of the gas. Gas extraction on non-mineral oils would require a longer extraction time due to the more viscous nature of the oil, to ensure adequate extraction. An equilibrium time of between ten and fifteen minutes is proposed to ensure sufficient extraction of the dissolved gases.

Sampling has been one of the problem areas for a very long time. Because of the nature of hydrogen and carbon monoxide gas, these two gases are lost first from the sample when sampling is done in an improper manner (gas bubble formation or headspace in sampling container).

Identification of Faults in Non-Mineral Fluids

DGA interpretation methods for mineral oils are based on many cases of transformers in service where gas formation could be attributed to a specific type of fault detected by visual inspection. This is not the case for non-mineral fluids.

The same key gases are formed during the chemical breakdown processes of oil and paper in both mineral and non-mineral fluids – the ratios might slightly differ. The type and composition of gas formation depends on the degree of localized temperature rise or energy contained in a fault because the energy needed for scission of molecular bonds and their recombination into different gases is not similar. The interpretation of the DGA results also has many similarities although different Duval triangles and pentagons are used for mineral and non-mineral fluids, as the zone boundaries had to be adjusted for non-mineral oil data interpretation. It should be noted that there are different types of non-mineral fluids e.g. silicone fluid, natural ester, and synthetic ester. Natural and synthetic esters can be divided into different categories again, which complicates the whole analytical scene for these fluids, as you are not working with one specific molecule type, but a vast pool of different molecules. Each one of these fluids might act just somewhat differently in the same electrical and thermal stress conditions than the next one.

It should be noted that ester fluids generate more gases in total than mineral oil, but these are not dissolved in the oils.

This implies the need for comprehensive analytical monitoring, firstly of the new fluid that would be used in the equipment in order to establish baseline data, and then the interval monitoring of these units under different stress conditions to record the actual outcome of each type of natural and synthetic ester. All these fluids will behave slightly differently under electrical or thermal stress situations and not all the details on these reactions have been stipulated yet.

The appearance of “stray gassing” is higher in non-mineral oils and the relevant tools are provided to distinguish the “stray gassing” phenomenon from the more serious faults like carbonization of paper. This is particularly true for natural esters, which produce significant amounts of hydrogen and ethane, but mainly ethane gas at relatively low temperatures, between 90°C to 200°C [3], which is considered only mild overheating. The higher stray gassing tendency for FR3, a natural ester, has tentatively been related to the higher viscosity and/or additives in the oil. Silicone fluid, on the other hand, displays very little “stray gassing”. Despite even higher viscosity, this fluid type produces only hydrogen when “stray gassing” and only from 180°C up to 220°C.

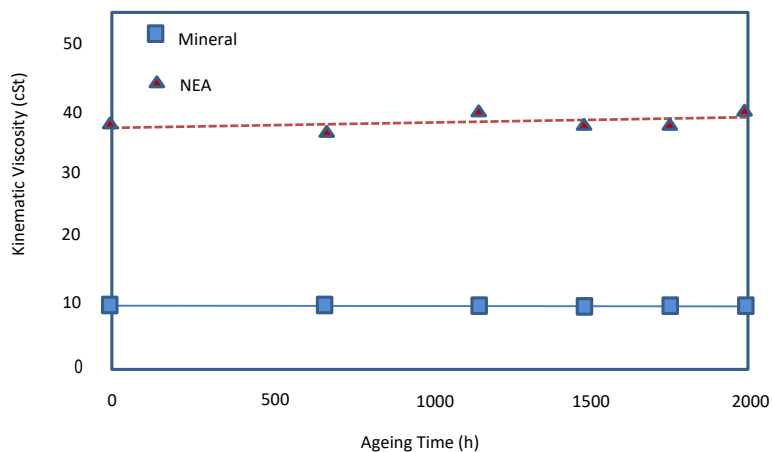


Figure 2. Kinematic viscosity in relation to time for mineral oil and natural ester



Typical Concentration of Key Gases in Non-Mineral Fluids

For electrical faults and especially for low energy discharges, the same main gases (hydrogen and ethylene) are created in relatively the same ratios, thus confirming the efficiency of key gas method for ester fluids. For thermal faults, and especially for stray gassing issues (low thermal faults), ethane associated with hydrogen constitutes the key gas of natural esters.

Considering the different gassing behavior of commercially available non-mineral insulation liquids (silicone and ester fluids) Duval Triangle 3 has been developed.

The typical concentration values in service for these key gases are lower than with mineral oils. It was found in experimental data that the IEC gas ratio method is not well adapted for natural esters, especially to define the discharges of low energy (D1) [4].

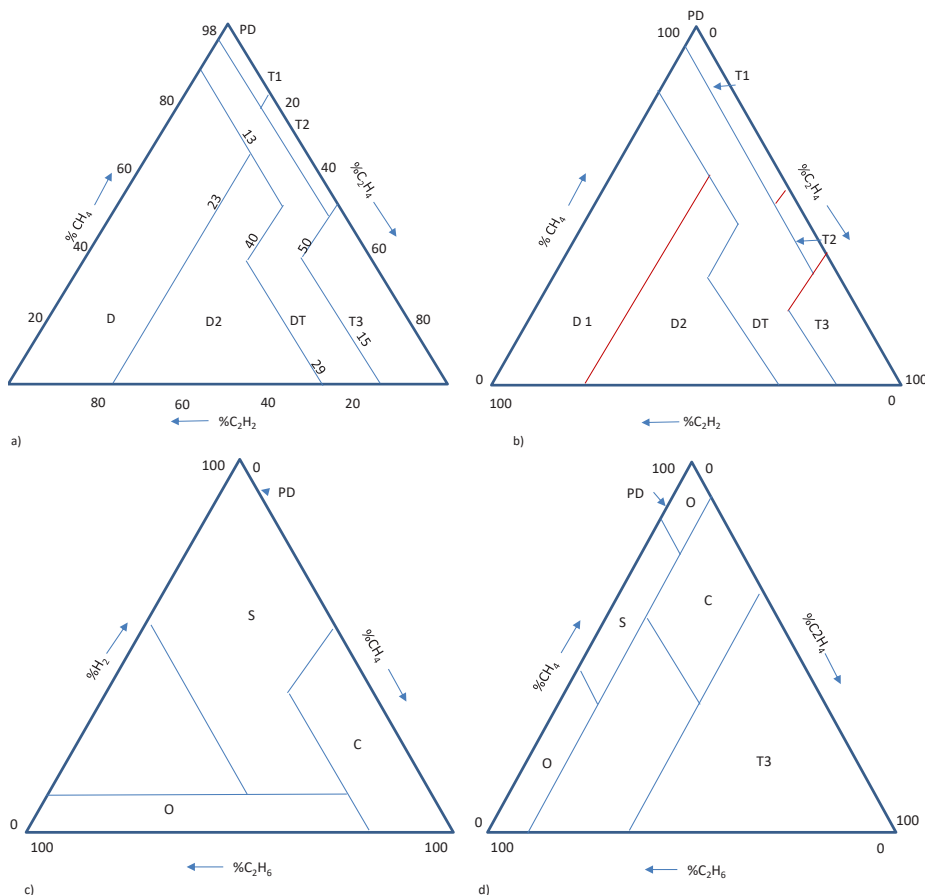


Figure 3. Duval Triangle: (a) Triangle 1, (b) Triangle 3 for FR3, (c) Triangle 4, (d) Triangle 5

Oil Type \ Gas	H ₂	O ₂	N ₂	CH ₄	CO	CO ₂	C ₂ H ₂	C ₂ H ₄	C ₂ H ₆	C ₃ H ₆
Mineral	0.0504	0.172	0.091	0.423	0.125	1.1	1.25	1.81	2.88	9.64
FR3	0.0471	0.134	0.074	0.341	0.108	1.54	2.58	1.67	2.14	7.46
MIDEL	0.0479	0.152	0.091	0.378	0.13	2.08	4.26	1.85	2.2	7.67
Silicone	0.0869	0.267	0.155	0.58	0.189	1.63	2.04	2.18	3.1	9.91

Table 2. Solubility/partition coefficients k of gases in mineral and non-mineral fluids at 20°C

Boundaries between zones	Mineral oils	Silicone oil	Midel	FR 3	Bio Temp
D1/D2	23	9	26	25	20
T1/T2	20	16	39	43	52
T2/T3	50	{46}	{68}	63	{82}

Table 3. Fault zone boundaries for non-mineral fluids (when different from mineral oils) in % C₂H₄

The Duval pentagon is a graphical DGA interpretation technique which is based on the use of four main hydrocarbon gases: methane, ethane, ethylene, acetylene and hydrogen. Each summit in the pentagon corresponds to one gas. In this technique, relative percentages of each hydrocarbon gas are plotted on the axis between the center (0%) of the pentagon and the pentagon vertex (100%). The Duval Pentagon 1 allows identification of six basic electrical and thermal faults (PD, D1, D2, T1, T2 and T3); Pentagon 2 enables identification of three electrical (PD, D1, D2) and four advance thermal faults (T3-H thermal fault in the oil, C – Carbonization of paper, O – Overheating (<250°C) and S – stray gassing of oil).

The typical gas concentration values seem to be lower than for mineral oil, possibly because it takes higher temperatures to form these gases with such fluids, or because there is not enough data available so far to be really representative of their actual behavior in service. Most of the data available is experimental.

Furan Analysis

The thermal degradation of cellulose paper that is used in electrical equipment will lead to the formation of a class of heterocyclic compounds. These include 2-furfural-eldehyde (2-FAL), 2-acetylfuran (2-ACF), 2-furoic acid, 5-methyl-2-furfural

(5-MEF), 2-furfuryl alcohol (2-FOL) and 5-hydroxymethyl-2-furfural (5-HMF).

IEC 61198 and ASTM D5837 are used to determine the presence of these chemical components in the transformer oil. This method allows for detecting trace quantities of these compounds in the parts per billion range. The furanic compounds dissolved in insulating oil are solely related to the degradation of paper insulation in the system. Cheim et al [5] have reported the existence of a linear relationship between DP value of cellulose paper insulation and 2-FAL concentration dissolved in mineral oil in logarithm scale.

Experimental data compared the decrease of the DP value of pressboard in both mineral oil and natural ester fluids. In Figure 5 (left) we notice that the average DP of pressboard decreases quite rapidly

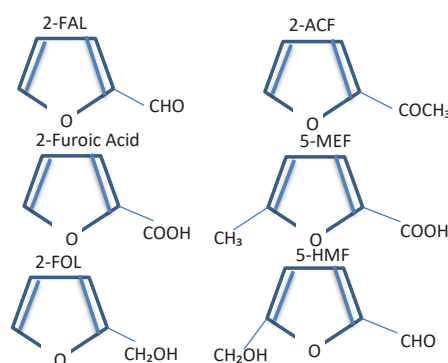
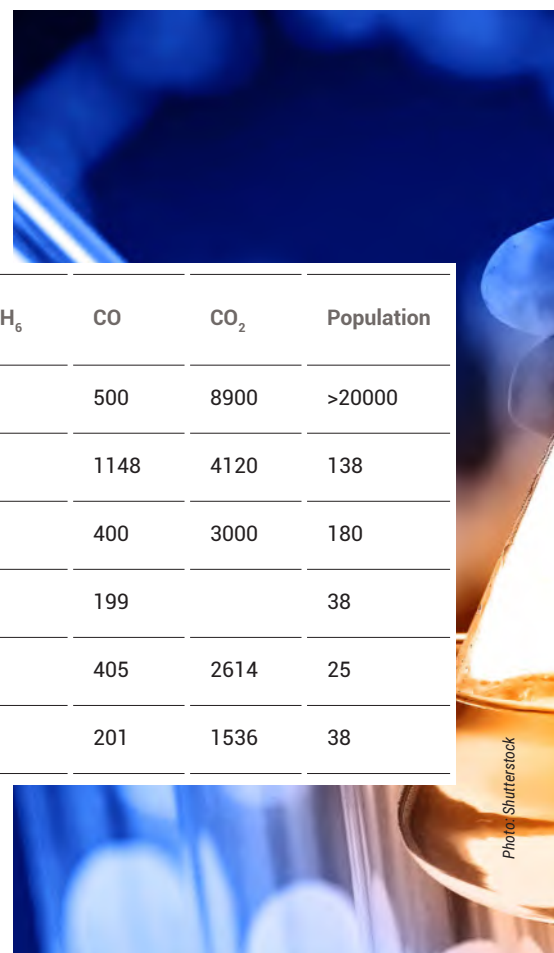


Figure 4. Chemical structures of furanic compounds

at the beginning and then the rate of decline is lower regardless of the type of oil used. This is due to the chemical features of the cellulose molecules in the pressboard and not the oil. The long chain cellulose polymer in new pressboard may contain weak links in the middle, which occur naturally in every 500 glucose monomer units. These links are weak and rapidly break under thermal stress, which accounts for the first drop in DP value. Amorphous regions break more easily than crystalline regions, and this phenomenon also supports the quick initial aging. Most water and acid produced during ageing reactions sit in the amorphous regions because of their greater permeability. The crystalline region, on the other hand, does not allow water and acid penetrations as readily.

Figure 5 (left) clearly indicates that the reduction in DP of pressboard insulation in the presence of natural esters is substantially lower than in those transformers filled with mineral oils. It should be noted that the initial moisture content for mineral oil and natural ester was nearly the same at the start of the experiment.



Oil Type	Network	Traction	H ₂	CH ₄	C ₂ H ₄	C ₂ H ₂	C ₂ H ₆	CO	CO ₂	Population
Mineral	X		100	80	170	3	55	500	8900	>20000
MIDEL (Ref 1)	X		37	68	70	1	50	1148	4120	138
FR3	X		35	12	12	1	20	400	3000	180
BioTemp	X		41	7	5	1	4	199		38
Silicones		X	25	28	1	1	0	405	2614	25
MIDEL (Ref 2)		X	21	7	9	2	2	201	1536	38

Table 4. Examples of 90% typical concentration values observed in non-mineral oils

The DP value decrease in natural ester filled units was negligibly small during the experimental period, and the DP was 100 to 150 higher than the DP of pressboard aged in mineral oil. According to these findings, natural esters show resistance to ageing of cellulose paper insulation.

It is clear from experimental data that a unit operating at 110°C should have a decrease in life expectancy of a factor of 27 due to the increase in moisture to about 2.2%, while that in natural ester with 2.4% moisture is only reduced by a factor of 15. This behavior pattern for pressboard can

be applied to cellulose paper as they are of the same molecular structure.

Neutralization Number (Acidity Value)

In the case of mineral oils an increase in the acid value mainly gives an indication of the degree of deterioration of the oil under oxidizing conditions.

However, a rise in the neutralization number of synthetic and natural esters does not merely give an indication of the oxidizing conditions because hydrolytic degradation of esters also

yields acids. Degradation of cellulose insulation releases water, and hydrolysis reactions in ester fluids in a transformer could become extensive with time. Synthetic esters mainly produce short chain acids and these acids accelerate the ageing process of paper insulation creating corrosion on copper conductors.

The hydrolysis reaction in natural esters produces long chain fatty acids and these are not harmful to the insulation system or other components of the system.

Different limiting values for neutralization values for different types of oil have been proposed. For example, the British standard EN 61203 proposes that for synthetic esters with a voltage rating of 35 kV or lower, the neutralization value should be less than 2 mgKOH/h, while acceptable maximum values in mineral and natural ester fluids of <69 kV should be 0.2mgKOH/g and 0.3 mgKOH/g, respectively. However, some studies have shown better ageing performance of cellulose material in natural esters with a higher acid level, therefore the proposed limiting neutralization value for natural esters is arguable.

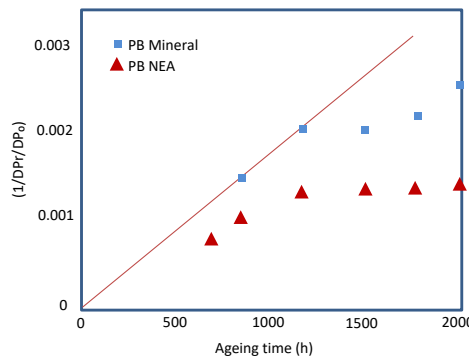
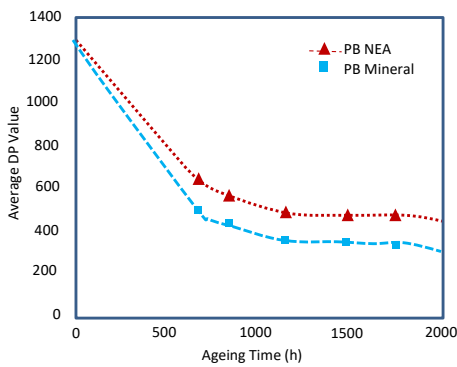


Figure 5. Decrease of DP values of PB impregnated with mineral oil and NE (left), and 1/DPt 1/DP0 versus ageing time of PB (right)

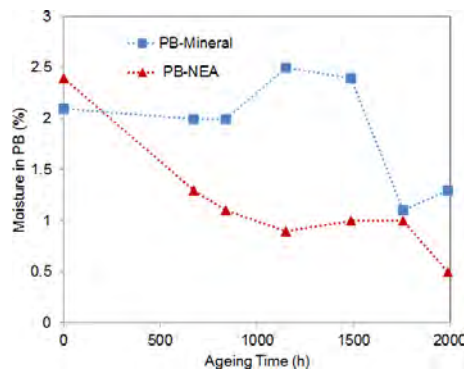


Figure 6. Change of moisture in PB over aging

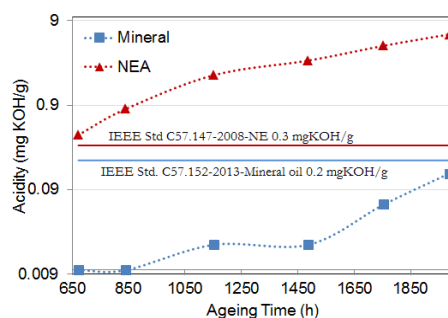


Figure 7. Change of acidity over time

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NYTRO® THE NEW
BIO 300X BIO-BASED
ALTERNATIVE
FROM NYNAS

NYTRO® BIO 300X

is a bio-based hydrocarbon which has the look and feel of a great mineral insulating oil, and yet it provides a sustainable and environmentally sound solution without compromising performance.

Is NYTRO® BIO 300X a Mineral Oil or an Ester?

NYTRO® BIO 300X is neither a mineral oil nor is it an ester – It is a bio-based hydrocarbon which is readily biodegradable and of ultra-low viscosity. What this means in practical terms is that it has the look and feel of a great mineral insulating oil and yet it provides a sustainable and environmentally sound solution without compromising performance. It has the best of both worlds. Furthermore, natural esters have significant disadvantages; namely, poor oxidation stability, high viscosity and inferior dielectric properties in many conditions [1-5] – these all mean in practice the re-designing of a transformer, which usually costs more than one filled with mineral insulating oil. NYTRO® BIO 300X has excellent oxidation stability, low viscosity and much more similar dielectric properties compared to mineral oils than esters. In addition, NYTRO® BIO 300X provides the lowest viscosity profile of any bio-based insulating liquid in the market today, allowing thermal optimisation of a transformer due to improved convective heat transfer. NYTRO® BIO 300X meets and exceeds IEC 60296 Ed 5 (2020).

Bio-based and Biodegradability – What is the difference?

NYTRO® BIO 300X is both fully bio-based (ASTM D6866) and readily biodegradable (OECD 301) but often these two concepts are confused. A bio-based product is one that is comprised of materials of biological origin apart from fossil materials and/or those incorporated into geological formations. The bio-based carbon content of a substance is a smart way of checking whether the actual material itself is predominantly bio-based where radiocarbon analysis of the Carbon-14 is used. NYTRO® BIO 300X comprises of >99% bio-based carbon, and as such is a fully renewable hydrocarbon. In addition, NYTRO® BIO 300X is readily biodegradable, but this has virtually nothing to do with the fact that it is bio-based. Biodegradability is a question of whether or not in nature the substance can be effectively broken down by living organisms. NYTRO® BIO 300X is a very pure, non-ecotoxic hydrocarbon, with relatively low average molecular weight compared to typical mineral insulating oils and these are the main reasons why it is readily biodegradable. In conclusion, if an insulating liquid on the market is claimed to be readily biodegradable this does not speak whatsoever to the origin of the material itself.

Questions to always ask about an alternative liquid:

- ✓ What is the bio-based carbon content?
- ✓ Is it readily biodegradable?
- ✓ Is it recyclable?
- ✓ What additives at what concentration are used in the product?



NYTRO® BIO 300X
is both fully bio-based
and readily biodegradable.

What about Carbon Footprint?

Accounting for raw material sourcing, transports and production (cradle to gate) as well as the carbon sequestration by the feedstock during early life, NYTRO® BIO 300X has a negative carbon footprint. If compared to natural esters – which are vegetable seed oil based, they will typically have a higher carbon footprint. NYTRO® BIO 300X is also competing far less with food-crops. This is because most natural esters are made from the same oils that are used in the food industry. In the case of NYTRO® BIO 300X the majority of feedstocks are by-products rather than the main crop itself. In many cases the water usage footprint of vegetable crops is very high, and this should be taken into consideration when evaluating a bio-based product. NYTRO® BIO 300X is also fully recyclable and the reclamation and re-refining technologies that are used today on mineral oils are completely sufficient to be applied on NYTRO® BIO 300X. In comparison, the recycling technologies available for ester liquids is limited. Re-refining via hydrotreatment is not an option for esters, but it is for hydrocarbons. Reclamation via adsorbents (such as clay) is more complicated for esters due to their polar nature and the different additives which may need to be replaced.



NYTRO® BIO 300X has outstanding oxidation stability meeting and exceeding the highest requirements on the accelerated ageing tests according to IEC 61125, i.e. no significant acid production after 500 hours at 120°C in the test.

Why is Oxidation Stability important?

It is well known in the energy industry that power transformers are expected to have a long useful life, usually 40 years. In fact, even longer design lives are desired to improve capital expenditure and for better sustainability. Utilities and asset operators do not want to have to do any major maintenance on a transformer over this period. Insulating oil maintenance usually involved activities such as inhibitor top up, oil reclamation or oil replacement. To minimise required insulating liquid maintenance using a product with excellent oxidation stability is the best solution. NYTRO® BIO 300X has outstanding oxidation stability meeting and exceeding the highest requirements on the accelerated ageing tests according to IEC 61125, i.e. no significant acid production after 500 hours at 120°C in the test. Natural esters have very poor oxidation stability (typically only 48 hours in the same test and they produce acids) as a consequence, natural esters are only really a viable solution in hermetically sealed transformers in a distribution context. As transformers get larger than around 1 MVA and above 33 kV, it becomes more challenging to achieve a hermetically sealed design (due to thermal expansion and contraction). Mid-size and large power transformers will typically have a conservator and even if a rubber bag is employed, the use of natural ester should be carefully considered because if there is oxygen ingress, the natural ester will experience much faster oxidation than utilities are accustomed to with mineral oils. NYTRO® BIO 300X has no limitation for use in fully free breathing transformers thanks to its excellent oxidation stability.



Insulating Liquid	Viscosity at 40°C
NYTRO BIO 300X	3.7 cSt
NAPHTHENIC MINERAL OILS	7.6 – 11 cSt
SYNTHETIC ESTERS	29 - 34 cSt
NATURAL ESTERS	32 – 40 cSt

Why is Low Viscosity important?

A power transformer is first and foremost an electrical machine, but coming in at a close second, it is a thermal machine. Heat is generated due to the losses, and ambient temperature as well as load fluctuations lead to temperature gradients within the unit itself. Heat must be removed as efficiently as possible to ensure a transformer will operate reliably over the many decades of its operational life. The insulating liquid acts as a heat transfer fluid and lower viscosity means better heat transfer, and lower temperatures. Natural and synthetic esters are much thicker and more viscous liquids than mineral oils and compared to NYTRO® BIO 300X they are about 10 times more viscous. Practically, if one took a transformer of a certain design, and only changed the liquid and nothing else, the one filled with NYTRO® BIO 300X would have a significantly lower winding and hot spot temperature, typically 8 to 15 degrees lower than the one filled with ester, depending on the transformer's design. Lower viscosity liquids lead to lower temperatures for a given design, especially where (liquid) natural convection is employed [6]. With NYTRO® BIO 300X, transformer designs can be optimised to potentially save on copper and overall size, because of the expected reduced temperature on standard design (mineral oil), and thus providing a significant margin to the guaranteed temperature rise requirements.

How important is Fire Point?

Natural and Synthetic esters have higher fire points than typical mineral insulating oils but the positive impact this has on transformer reliability is often exaggerated. First of all, the fire point of a liquid speaks only of its combustibility, not of its electrical behaviour within the transformer. In fact, both natural and synthetic esters are more likely to initiate electrical discharges, in certain situations, in a transformer than mineral oils and their ability to quench the arc itself is less effective than it is in mineral oils [1-3, 7, 8]. As a consequence, ester filled transformers are usually designed with higher electrical safety margins and are mostly limited to vacuum type tap changers. Both mineral oil and ester filled transformers can explode [9]. The risk of an explosion in a transformer is not related to its liquid's fire point but rather to the pressure wave a sudden electrical arc will cause and whether the tank can handle the pressure wave. What is debated is the consequential fire. It is rather well known in the industry that, historically, the root cause of the majority of transformer fires was bushing and tap changer failure [10], with both technologies becoming much more reliable in recent years. The issue needing more debate and investigation in the industry is: if the bushing and tap changer are of a modern, safer design, does the overall consequential risk of transformer fire really get significantly improved by moving to an ester liquid? Combined with the fact that esters have worse, not better, dielectric properties, and dielectric failure being often the main issue in transformers [10], one needs to critically evaluate the true benefit of a higher fire point.



Does the transformer design change?

As NYTRO® BIO 300X shares much in common with the best mineral insulating oils, for the most part transformer designs will remain unchanged. The lower viscosity of the liquid (better heat transfer) will in fact incentivise thermal design optimisation. Through close collaboration with leading transformer manufacturers, tap changer manufacturers and research institutions, a large body of scientific know-how already exists on the product. Typically, tap changer ratings used for mineral oils can be applied (whereas more safety margin is normally needed for esters [1]) and the overall dielectric design of the transformer is expected to remain mainly unchanged (whereas for esters electrical design rule changes are usually required [2]). As already mentioned, due to excellent oxidation stability, there is no restriction for the type of preservation system and free breathing transformers can be used.



Can I use existing diagnostics?

NYTRO® BIO 300X is a hydrocarbon-based liquid much more like mineral oils than ester liquids. Ester liquids have a completely different chemical composition and as such there have been many questions into the type of gases they will produce under fault conditions and whether current day DGA rules are applicable. Moreover, ester liquid usually contains different antioxidant additives (and more of them) than used in inhibited mineral oils, so there are also questions around liquid ageing, and inhibitor management. For NYTRO® BIO 300X the same inhibitor is used that is used in other NYTRO® naphthenic based inhibited insulating liquids and the same inhibitor monitoring and top-up regimes apply. Regarding DGA, no significant differences in DGA interpretation to existing mineral insulating oils are expected, due to similarity in chemical composition with other mineral and hydrocarbon based insulating liquids; nonetheless, ongoing and continuous research will supplement the body of knowledge over the next years.

How do things change on site?

A practical challenge ester liquid brings to the table is the need for two sets of oil treatment equipment as well as different on-site filling practices. Firstly, cross contamination between an ester and a mineral insulating oil can ruin the properties of the mineral oil – for example, properties such as the Inter Facial Tension (IFT) and Dielectric Dissipation Factor (DDF) can change drastically. As a consequence, product segregation between mineral oils and ester liquids is needed. Ester liquids have higher viscosity and higher water retention than mineral oils and as such will require different treatment rates in oil purification plants. The filling process in the transformer will also take longer and be more complex as the insulation impregnation time will take longer for ester liquids [11-13]. For NYTRO® BIO 300X flushing between products will be sufficient to enable the use of the same treatment plants and pipes, and the filling process can remain the same as for mineral oil. In fact, the insulation impregnation rate will be faster than for mineral oils because of the product's low viscosity.





Conclusion and summary

NYTRO® BIO 300X is one of the most exciting innovations in the insulating liquid space in recent years. With keen interest from the market, NYTRO® BIO 300X will be at the forefront of the drive towards improved sustainability of transformers. This is achieved both by the lower carbon footprint of the material itself combined with the potential for a lower energy footprint of the transformer. If the transformer designer makes use of the improved heat transfer the liquid offers and the transformer has a lower winding temperature than the specification limit, then load losses will be reduced for the same load. NYTRO® BIO 300X shares many similarities with the best mineral insulating oils but has the added benefits of being fully bio-based, readily biodegradable and of ultra-low viscosity.



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CTO at EkoFluid GmbH

Interview with **Peter Grolimus**



“When offering a complete solution for transformer insulating liquids in the European market, the validations and innovations performed with Ekofluid were a key factor.”

Alan Sbravati
Global Technical Application Manager
Cargill BioIndustrial - Dielectric Solutions

Peter Grolmus



Photo: Ekofluid

 Ekofluid

Peter works as the Chief Technological Officer at Ekofluid GmbH and his work at Ekofluid is simple. If you do not know how something works, he's the guy to explain it to you – but be ready for a lecture.

We asked Peter Grolmus the CTO at Ekofluid GmbH to tell us more about the innovations in the field of oil treatment and oil regeneration equipment.



Transformer Technology: Oil treatment equipment today looks the very same as it looked many years ago. Can you explain why?

Peter Grolmus: Indeed, you are correct. Most oil treatment equipment on the market is still being built the same way it was built twenty or even forty years ago. Sure, some of the components themselves have changed, but the overall design, and most importantly functionality, remains the same.

TT It seems that there is an evident lack of innovation in the field. Do you know why?

PG We have done several surveys and talked to many of our longer-term customers and what we discovered is that the innovation push will not come from them. They were all happy with their current equipment. They had procedures set up to operate and maintain that equipment, and more importantly, they had people trained to handle the equipment. When we analyzed this, we realized that the drive for innovation will not come from the customers and therefore it had to come from us.

DRIVING INNOVATION IN TRANSFORMER OIL TREATMENT

TT So, you are saying that the innovations that you have introduced in the market in the recent years were not customer driven?

PG Indeed, you are correct. The innovations were pushed by us, the manufacturer. The moment we found out that the push will not come from the customers, we first needed to answer the big question. Is there even a need for innovation in the oil treatment field? Surprisingly, this question was answered quickly. All we had to do was look around at our component suppliers, at the tools we used in production, and see that basically anywhere around us there was innovation. We even had suppliers coming to us saying, "We have these great new exciting products on the market, why are you not using them in your equipment?"

TT That is interesting. What was your reply to that?

PG Well, the initial reply was that our customers do not want them, but then after some consideration, the reply has changed to, "We do not know how they will benefit our customers." And after this realization, everything changed. We stopped looking for ways to innovate our equipment because we wanted to do innovation, but we asked ourselves the most important question - How can we make our equipment better for our customers, through innovation?

TT So, in other words, you have changed your perspective on innovation?

PG Indeed, we did. We defined several areas in which we wanted to improve our equipment and started looking for ways to do it - through innovation. The main areas we defined were Performance (Results), Safety (Handling), Manufacturing (Delivery), and Training (Support). We decided that for this to make sense, we need one major, and several minor improvements in each of these areas, either on the equipment itself, in our manufacturing process, or in customer support. But on one very important condition - Whatever we do, it must benefit the customers, otherwise it does not make sense.

TT Before we dive into the specifics of your innovations, could you tell me more about your process?

PG In fact, the process was straightforward. We knew that our customers would bring us very little in terms of innovation requirements, we addressed this issue as well, so we went to the "next big thing" - our own onsite service teams. It might be a little unknown to many as we are primarily seen as a manufacturer,

but in fact, we operate the largest onsite regeneration, corrosive sulfur removal and oil treatment equipment fleet in Europe. Naturally, all our onsite teams use our own equipment. So, what we did was involved our service team leaders and started asking them how to improve the equipment. And we did get the right answers.

TT You mentioned that you also addressed the issue with customers not really asking for innovations?

PG To be fair it is not all customers and, when we approached them with our new product, the acceptance was much better than we anticipated. Now coming back to your question. We realized that some customers simply want the same equipment they have had for the last 20 years and preferably with as little change as possible. So, what we did is we separated our product lines and we created a new oil purification line we call **ECOIL**.

The ECOIL line closely copies the original equipment that has been on the market for many decades. Internally we call them “old style” units.

TT Could you now describe in more detail those individual innovation areas we talked about earlier?

PG Since I know I need to keep this short, I will concentrate only on one major improvement in each area, but I think I should first introduce the product line. We call this our advanced product line of transformer oil treatment equipment, named **FILOIL**. I think it is best to start with performance as at the end of the day this is the key improvement that our customers are interested in.

We knew we wanted to improve three things: foam handling as we knew this is always an annoyance for all our service teams; speed, and the actual results. Now if you want to improve all



these things, they all converge into one point in the equipment and that is the vacuum chamber. We did a lot of research on the old style “raschig rings” systems as well as the more modern coalescer systems, which resulted in creating our new stadium shaped vacuum chamber. We know the drawbacks of both technologies - the Raschig rings system tends to overtreat oils and since they simulate the distillation tower design, they are very prone to evaporate light fractions of oil. On the other hand, the coalescer systems have tendency to extensively foam with higher water contents. So, what we did, we put both technologies into one vacuum chamber eliminating their weaknesses and improving their strengths. Thanks to the new stadium design vacuum chamber, we also improved on foam control and by active vacuum regulation with the help of computer algorithms and in-house developed sensors, we now have absolute control of our vacuum and foam. At the end of the day, all these improvements allow our

equipment to be faster and more efficient with absolute foam control.

TT That sounds very interesting. Could you also elaborate on the other innovation areas that you mentioned?

PG For us, the next important innovation area is safety. What we did here was also quite interesting. We have been on the market for more than 25 years, so we compiled a historical list of all accidents and near accidents that have happened to our onsite teams. We grouped the list into common categories and then asked our manufacturing and IT how we could prevent these accidents. Without going deeply into the process, at the end of the day we ended up placing a lot of sensors, blocks, alarms and warnings across the equipment to make it as safe as possible. I am proud to say that now it is almost impossible to damage either the equipment (or harm the operator) or the transformer you are working on with any incorrect operation. The equipment will either stop you or it will shut down not allowing for any accidents to happen. What I am especially proud of is that we were also able to transfer, not all, but many of these safety features over to our ECOIL product line.

TT And what about the innovations in your manufacturing process, I am quite interested in that.

PG Our manufacturing process has been heavily affected in the same ways as every other manufacturing company out there. Everything has been digitized and we are working with the latest tools that are available. However, what we did was we used this shift to digital and we completely changed the way how we sell and build our equipment. When we saw what capabilities we have been given by modern software and manufacturing tools, we translated all of this into a huge customer advantage. We allow our customers to completely customize their equipment before they buy it. We have more than 60 customization options the customer can choose from before we even begin the manufacturing process. We found this to be one of the greatest benefits for our customers from our innovation process. I personally love to see how each customer is going through the options and basically configures the system to completely suit their needs and requirements.

TT Now let’s discuss your last innovation area, if I recall correctly, it is training and support?

PG Yes, it is. But here I have a little confession to make. All the innovations we have discussed above would not be possible with-

It might be a little unknown to many, but we operate the largest onsite regeneration, corrosive sulfur removal and oil treatment equipment fleet in Europe.



out software and hardware to run it. I intentionally did not discuss our R&D in software and hardware when in fact all innovations were primarily driven by it. During the process we realized that while they have been crucial for us, they are almost non-existent for the customer. Sure, they see the operating screen and the interface, but this is where it ends for them. It is normal for the customer to not care about how it works if it works. However, there is one point where it suddenly all becomes too important and that is when things stop functioning properly. We discovered that the moment we need to support our customers and troubleshoot their mistakes, software and hardware can do miracles for the customer. To explain this in short, our equipment gathers lots of data during operation, we analyze this data and if the customer runs into a problem, we use this data to help them. All these amazing new tools that we now have (also partly to Covid) have become standard, such as remote support, video live stream support, operational screen mirroring, cloud data analysis, and video manuals and tutorials we can offer to our customers thanks to our robust software and hardware framework that we have developed.

TT Now to change the topic a little bit, do you also manufacture transformer oil regeneration equipment?

PG Indeed, we do as well as corrosive sulfur removal equipment. Our transformer oil regeneration equipment is sold under the brand name **REOIL**. We manufacture equipment with the conventional method as well as with the new reactivation method. But in all honesty, I believe that the regeneration topic is so vast it would be best suited for a standalone interview.

TT Indeed, I agree but before I let you go, I do have one last topic I would like to discuss. What about Ekofluid and synthetic and natural ester fluids?

PG I could give you the official answer that all our equipment is approved (and rated) to work on synthetic and natural esters. However, the answer goes deeper than that.

We have had tremendous growth in the recent years, and we developed some amazing products bringing innovation into a field that has not had any innovations in several decades.



We do have several special relationships with oil manufacturers and a very strong one with a prominent natural ester manufacturer. In fact, some of our products are used directly in production of these fluids and we therefore proud ourselves on having one of the best, if not the best, knowledge and know-how to handle these fluids and how to build equipment that can efficiently handle them.

TT Does this mean that all your equipment is capable of working with these oils?

PG Indeed, it is so. We have drawn our experience from working with oil manufacturers who have been producing ester fluids for some time, but also from our relations with transformer manufacturers who have been using ester fluids for many years now. We have taken this experience and transferred it into our equipment with a single condition in our mind. We do not want to force our customer to make a choice. Regardless of the type of transformer oil he wants to treat, it should always be the same equipment from us. And I believe we have achieved this mission as we do not have a dedicated product line for any specific transformer oil type. Both our product lines, FILOIL and ECOIL, are designed to work virtually with any type of transformer oil.

TT And before we finish our interview, what is next for Ekofluid? Where do you see Ekofluid and your products in the next five to ten years?

PG Ekofluid is an extremely dynamic company. We have had tremendous growth in the recent years, and I believe we have hired the best possible talent there is to hire. They have developed some amazing products and brought innovation into a field that has not had any innovations in several decades. We feel that the products we have created are from a different dimension if you compare them to what is available on the market today. Yet, for us this is just the beginning. Our vision for the next five to ten years is pretty simple. We want our equipment to be not automatic, but autonomous.

Your one source supplier of electrical insulation and wire materials for the motor and transformer industry.



PRODUCT LINE

- Magnet Wire (Also available in 6" spool)
- Insulation Materials (Slot Insulation, Wedges, Phase Insulation and others)
- Rigid insulation (Sheets, Rods, Dog Bone)
- Varnishes & Liquids
- Tubing and Sleeving
- Tapes & Adhesives
- Lead wire
- Telecommunication & Building Wire
- Specialty Papers & Fibers (Nomex, NMN, Copaco and others)
- Transformers Cores
- Pressboard
- Misc Supplies



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Q&A

UNDERSTANDING THE IMPORTANCE OF ADVANCED TRANSFORMER OILS

AN EXPERT
Q&A WITH ED
VAN SCHAİK,
PRODUCT
APPLICATION
SPECIALIST,
SHELL





What do changes in power generation mean for transformer oils?

How we generate, transmit, and consume electricity is changing in ways which place a greater demand than ever on key infrastructure, particularly electrical transformers. From an increased need for power, which places stress on often aging infrastructure; to the siting of renewable power generation capacity in locations susceptible to extreme weather, transformers are required to deliver under more challenging conditions than ever before.

The increasing integration of renewable energy sources of generation – that are often situated away from population centres - into the grid, requires long-distance electricity supply – and higher voltages to ensure efficient transmission. This alone increases stress on electrical transformers which were often designed with much lower loads and lower operating temperatures in mind.

To maintain operation with peak performance, the industry needs new and smart transformers to meet those changing requirements on the oil - providing extended periods of reliable operations to enable transformers to work hard for longer; performing at the higher voltages required for longer distance electricity transfer; and operating under higher temperatures at the limits of transformer design specifications.

Meanwhile oil must be well equipped to support the transformers to be reliable in these more challenging environments – it also signals the influx of sustainable measures across the board; and this includes for the oil itself. Cradle to grave offsetting of emissions is at the front of many customers' minds; as is the recyclability and biodegradability of an oil – which is particularly important in environmentally sensitive locations.

At Shell Lubricant Solutions, our challenge is to develop and supply best in class transformer oils that will fulfil both today's requirements and those of the future. With more than 80 years of experience in the sector, we have developed a range of naphthenic and paraffinic oils; which we added to with our GTL options in 2013, and most recently with our biodegradable product this year as we look to ever evolve our offering ahead of market demand.



At Shell Lubricant Solutions, our challenge is to develop and supply best in class transformer oils that will fulfil both today's requirements and those of the future.

Q&A



Why are transformer oils so important in effective and reliable equipment operations?

Transformer oils are integral to the overall reliability of the equipment. They play an important role in securing the electrical supply and ensuring that equipment functions optimally.

While the high dielectric strength of advanced transformer oils means they act as an insulator where appropriate. Another key function is to enable efficient cooling in the equipment. A poor-quality transformer oil can quickly oxidise which forms sludge which will then block the cooling tubes. Whereas an advanced option, such as those in Shell's GTL range of transformer oils have high oxidation resistance to mitigate this risk of sludge build up and therefore increase performance reliability. The cooler a transformer runs, the more energy efficient it can be, and helps preventing any unplanned cease of operate.

High sulphur levels are other implication of poor-quality transformer oils that can be costly for operators. When this sulphur comes into contact with the copper in transformers, it forms cuprous sulphide, which greatly reduces the dielectric properties of insulating materials, reducing their performance and increasing the chance of failure. The high temperatures at which many transformers now operate increases the likelihood that deposits of cuprous sulphide form.

A range of factors has increased the demands placed on transformer oil, and only through innovative responses to these challenges can power generators and suppliers guarantee continued quality of service, cost efficiency and return on investment.

Shell Lubricant Solutions has pioneered the innovation of oils based on its gas-to-liquids (GTL) technology, which converts natural gas into high-quality liquid products. GTL-based products contain almost none of impurities like sulphur, aromatics and nitrogen, making them ideally suited to use in high-demand environments such as electrical transformers.



What innovative technologies are the industry developing to meet the changes in the sector?

Shell Lubricant Solutions has pioneered the innovation of oils based on its gas-to-liquids (GTL) technology. GTL technology converts natural gas into high-quality liquid products. Electrical oils based on crude oil often have relatively high levels of impurities including sulphur, aromatics and nitrogen. In contrast, GTL-based products contain almost none of these elements, making them ideally suited to use in high-demand environments such as electrical transformers.



Shell has launched Shell Diala S5 BD, a GTL-based transformer oil which meets and exceeds specifications of Type A classification in IEC 60296 edition 5, 2020, is suitable for use in environmentally sensitive locations, being readily biodegradable, but does not compromise on performance or durability.

What is Shell doing to meet the need for next-generation transformer oils?

Shell has launched Shell Diala S5 BD, a GTL-based transformer oil which meets and exceeds specifications of Type A classification in IEC 60296 edition 5, 2020, is suitable for use in environmentally sensitive locations, being readily biodegradable, but does not compromise on performance or durability.

The new oil has a very low pour point: below -51°C . This, along with its good flow properties allow it to provide excellent cold temperature performance. It is robust in its resistance to ageing and degradation, has excellent heat transfer and cooling properties, and can enhance system efficiency, helping operators to reduce unplanned costly downtime.

Shell Diala S5 BD is compatible with standard mineral transformer oils (for ease of retrofitting) and meets the performance requirements of power transformers worldwide.

Transformer Oils Supply Chain in North America: Short and Long Term



by **Chris Kenney** President
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Chris Kenney spent the majority of his time in the refining industry in the sales and marketing of specialty hydrocarbon fluids, more specifically in transformer oil sales. Chris has worked in sales and sales management with Ergon Refining, Cross Oil, Petro Canada and most recently, Calumet Specialty Products. In all these assignments, he was at the forefront in business development roles dedicated to developing net new transformer oil market share. Chris is an expert in the technical aspects of both naphthenic and paraffinic transformer oils and has established worldwide contacts in the power transformer industry and US utility industry. Chris holds a Bachelor of Arts from St. Joseph's University, and currently resides in Acworth, GA with his wife Karen. Chris is available for either full, or part-time consultation arrangements regarding the sale and marketing of transformer oils.



Photo: Shutterstock

This article will focus on the history and current supply situation for mineral oil-based insulating fluids for distribution and power transformers in the North American market. The article is based on 40 years of experience working in the specialty base oil business, most of which has been spent working in the power industry with various specialty-based refiners, selling and marketing transformer oils to the power and distribution transformer OEMs and the utility industry, and building out national distribution supply chains to service the now robust field-fill market.

The supply chain for conventional naphthenic crude based insulation oils has changed greatly over those 40 years. The biggest change has not come so much in the specifications and chemical makeup of the insulating fluid, but rather in the refining companies that manufacture and sell the finished products. Until

the early 1990s, the so-called major oil companies, dominated the supply and distribution of naphthenic base oil transformer oils.

Naphthenics were the selected base oil because they exhibited the characteristics needed under the operating conditions experienced in large power transformers. Naphthenic crudes were wax free, had naturally occurring low pour points, lower aniline points, signifying good solvency properties, and were the preferred base oil to use. In the early days of base oil refining, paraffin-based oils were considered inferior to naphthenic base oils simply because they lacked these characteristics.

Until the early 1990s, the so-called major oil companies dominated the supply and distribution of naphthenic base oil transformer oils. Then, almost overnight, things began to change.

In the early 1990s, world's leading manufacturers of naphthenic base oils started closing their naphthenic refineries, while at the same time a number of small regional naphthenic refiners started upgrading their production.



Refining technology has changed greatly in how paraffin-based oils are refined to meet the demand for more precise technical requirements. These technical requirements for paraffin-based oils have been driven by the more stringent properties necessary to meet new generation motor oil specifications.

In the early 1990s, the dominant naphthenic refiners who supplied the market were Exxon, Shell Oil and Sun Oil. All three had specialty naphthenic refineries as part of their large refining complex. The brand names of Univolt, Diala and Suntrans were the accepted brand names used across the entire industry spectrum. Then, almost overnight, things began to change. There were growing fears among the major naphthenic-based oil refiners that naphthenic select crudes, vital to making naphthenic base oils, were beginning to play out. The domestic supply of low aniline naphthenic crudes was becoming scarcer and more expensive.

A major portion of the finished naphthenic base oil production went to process oils where aniline point was critical. Sun Oil, a worldwide leader in the manufacture and distribution of


naphthenic base oils announced the closure of its Marcus Hook naphthenic refinery in 1991. Exxon and Shell soon followed in announcing their intentions to exit the naphthenic base oil market. It just so happened a small naphthenic refinery in Vicksburg, MS, by the name of Ergon, in anticipation of this phenomena, had just finished expanding their new plant from 3,000 to 6,000 barrels a day. Another small regional Louisiana refiner, Calumet, had also just finished a brand new plant in Princeton, LA. Another small regional refiner, Cross Oil, has just finished upgrading their hydrotreating capabilities and entered the transformer oil market in 1992. Finally, a California naphthenic base oil refinery, San Joaquin, upgraded their naphthenic production in the late 1990s to manufacture severely hydro-treated naphthenic base stocks.

The upgrading of these smaller plants was not driven so much by the anticipation of larger competing refiners exiting the naphthenic business as it was by the 1984 OSHA requirements to clean up these base stocks for Polycyclic Aromatic Content. It had been proven earlier the high PHA content in a base oil could cause cancer through various

forms of occupational hazards either by direct or indirect exposure. If not for these providential plant upgrades by the smaller regional naphthenic refiners, there would have been a real supply chain interruption in supplying naphthenic base mineral oils to the power and utility users in the North American market.

Looking back over the recent past, we can see where power transformer OEMs and especially larger utilities would be well served to be proactive in staying current with the newest technology of mineral oil transformer fluids currently being offered to the market. In the early 2000s, Petro-Canada iso paraffin transformer oil was introduced to the American utility industry*.

The reception of the product, except for a few large utilities was lukewarm, since there was a sense that the current situation was adequate, where the saying, "If it isn't broken, then why fix it" applied. Technical interest in looking at a different base stock other than naphthenic was small. The same possible crude oil production constraints exist today for two prominent regional naphthenic base oil/transformer oil refiners.



Without the providential plant upgrades by the smaller regional naphthenic refiners, there would have been a real supply chain interruption in supplying naphthenic base mineral oils to the power and utility users in the North American market.

Naphthenic sweet crudes necessary to distill and hydrotreat conventional naphthenic base oil products are still more difficult to obtain on a ratable basis than conventional crude oils to make commodity distilled products. Plus, these light sweet crudes are more expensive than other benchmark crudes. The current premium for Louisiana light sweet (LLS) crude as reported by various public sources averages about \$2.00 to \$3.00 a barrel over WTI. Base oil production constitutes only 1% of all refining capacity. The manufacture of these transformer mineral oil based products is surely a specialty business.

Currently, there are quite a few major oil companies that are attempting

to market an iso paraffin – a highly refined base oil/transformer oil – to the power and utility industry. One large global refiner is offering a transformer oil refined by their gas to liquids technology (GTL). These products offer an excellent alternative to conventional naphthenic base oils. This refiner has made some significant inroads into the European transformer oil market urged on by large utilities specifying this product when filling their transformers. The science on these products is well established. They provide up to twice the oxidation stability, they have excellent low gassing tendencies, less aromatics, lower viscosities at 0°C and better overall thermal properties. In North America these products have received little attention.

Should the utility industry and power industry join forces to jointly develop strategies to broaden their approval lists to include the iso paraffin products? While the delta between the costs of the naphthenic oil as compared to the iso paraffin may be large, it is still a benefit worth considering given the experience in Europe. The viscosity grade necessary to make transformer oils is not expansive beyond the transformer oil application.

Although there is no crisis of supply for conventional naphthenic base oil transformer oils, we could see a pinch in supply due to some of the factors mentioned above. Change is always around the corner, most times when we least expect it. We believe that it is time for the utility industry and large power transformer producers to take a serious look at the iso paraffin products to lengthen their supply chain, lower long term costs and avoid supply interruption in the future.

Currently, there are quite a few major oil companies that are attempting to market an iso paraffin - a highly refined transformer oil - to the power and utility industry. These products offer an excellent alternative to conventional naphthenic base oils, but in North America, they have received little attention.

Editor's Note

- * The Author, Chris Kenny, was personally involved in the introduction of Petro-Canada iso paraffin transformer oil to the North American market

We believe that it is time for the utility industry and large power transformer producers to take a serious look at the iso paraffin products to lengthen their supply chain, lower long term costs and avoid supply interruption in the future.



bioTRANSOL TRANSFORMERS

IS THE ENVIRONMENTAL
SUSTAINABILITY A
RIGHT WAY TO GUIDE
TECHNOLOGY?



Various uses of Biotransol [1]

Biotransol HF is a dielectric fluid intended to use as an insulation and cooling medium in electrical distribution and power transformers. It is a natural ester-based dielectric fluid based on renewable vegetable oils.

The fluid is readily biodegradable as per US EPA OECD 301B, environmentally friendly and non-toxic to aquatic life [1].

Introduction

Biotransol has been used by various transformer companies in their oil filled power transformers all over Asia and North America. Indian manufacturer Savita oils, with over 40 years of experience in manufacturing dielectric fluids, has managed to craft Biotransol to take technology in the direction of environmental sustainability. According to Savita, "Biotransol is your ideal dielectric fluid in applications requiring higher levels of efficiency, safety and environmental consciousness" [1].

Biotransol benefits

Biotransol has several benefits over mineral oils. Efficiency, safety and eco-friendliness are some of them [1]. It has higher fire point, breakdown voltage and excellent biodegradable characteristics besides enhancing fire safety and environmental sustainability. The transformers manufactured using Biotransol as an insulating fluid can be used in high risk and highly populated areas.

//
When you have less space, and more population in that area [like in Mumbai, India], it means you need to have a solution that is very safe.

//
Ramchandran Pillai, Chief Corporate Operations T&D, Tata Power Co., Ltd. [2]



Oil-filled transformer

We don't just build to your satisfaction.



We build to exceed your expectations!

Benefits of Biotransol [1]

Efficient

- Faster moisture extraction from paper insulation while maintaining BDV, thereby increasing performance and extending life of your transformer.
- Slows ageing of transformer by enhancing life of solid insulation material.
- Transformer load can be enhanced as a result of diminished paper ageing.
- Reduces maintenance time and cost.
- Less consumption of fluid relative to conventional oils.
- Lower insurance premiums as a result of superior safety properties.
- Lowers cost of clean-up and impact in case of accidental spillages.
- Delays asset replacement and capex by prolonging the life of an aged transformer after Retrofill.

Safe

- With a high Fire and Flash Point (>320°C, >300°C), Biotransol significantly reduces risk of ignition and fire in case of accident.
- Enhances safety for workers during installation, maintenance and condition monitoring.
- Minimum damage in the event of spillage, as a result of its biodegradable nature.

Eco-Friendly

- Designed from entirely renewable sources.
- Reduces carbon footprint by being completely biodegradable.
- Non-toxic and eco-friendly to the environment and aquatic life.

Are we using Biotransol for manufacturing our transformers?

Atlas Transformer, a Toronto headquartered transformer company, has managed to use Biotransol in most of its oil-based transformers. This year we have delivered several natural ester filled transformers, meeting deadlines with high quality customer service. We have used FR3 fluid in all of our oil based transformers, allocating the benefits by reducing fire hazard and increasing life expectancy of its transformers [3].

One of the major Biotransol based projects that was delivered by Atlas Transformer this year for a Calgary based company includes a high voltage 5,000/6,250 kVA FR3 oil immersed three-phase substation transformer. One of its kind, with two pole 33 steps OLTC along with AVR, was engineered to high quality, manufactured, tested and delivered within 14 weeks after the approval was received [3].

Our engineers have been working on the idea of creating technology that is eco-friendly without lowering the energy efficiency. Another great example of natural ester filled transformer that was manufactured and delivered by Atlas Transformer to an Ontario based customer is a 10 MVA transformer of voltage class 27.6/13.8 kV with five-legged core design. This oil filled transformer was airlifted by Cathay Pacific and considered as one of the heaviest shipments in their airlifting career. The transformer was manufactured, along with a spare unit, within four weeks. The first unit was airlifted to meet the urgency and the spare unit was shipped by sea and arrived in November [3].



5,000/6,250 kVA FR3 oil immersed three-phase substation transformer

We don't just build to your satisfaction.



We build to exceed your expectations!



Why are we not using mineral oil?

Although mineral oil is a low cost, readily available and great dielectric oil, many studies have shown that it has caused more harm to the environment in the past few years. The environmental damage is usually related to oil leaks during transportation, transformer explosions and fires.

What is the vision of Atlas Transformer?

Atlas Transformer has changed their business model to accommodate eco-sustainability over profit. During its 30 years in transformer business, Atlas Transformer has recognized a large demand shift from Mineral oil-based transformers towards eco-friendly transformers. We at Atlas are engaged to provide products that are skillfully engineered for a high level of efficiency, resulting in low energy losses and exceptional build quality. Keeping that vision in mind, Atlas will continue to provide eco-friendly transformers as per market demands [4].

10 MVA oil-filled transformer of voltage class 27.6/13.8 kV with five-legged core design

Atlas Transformer - Power for every Application!

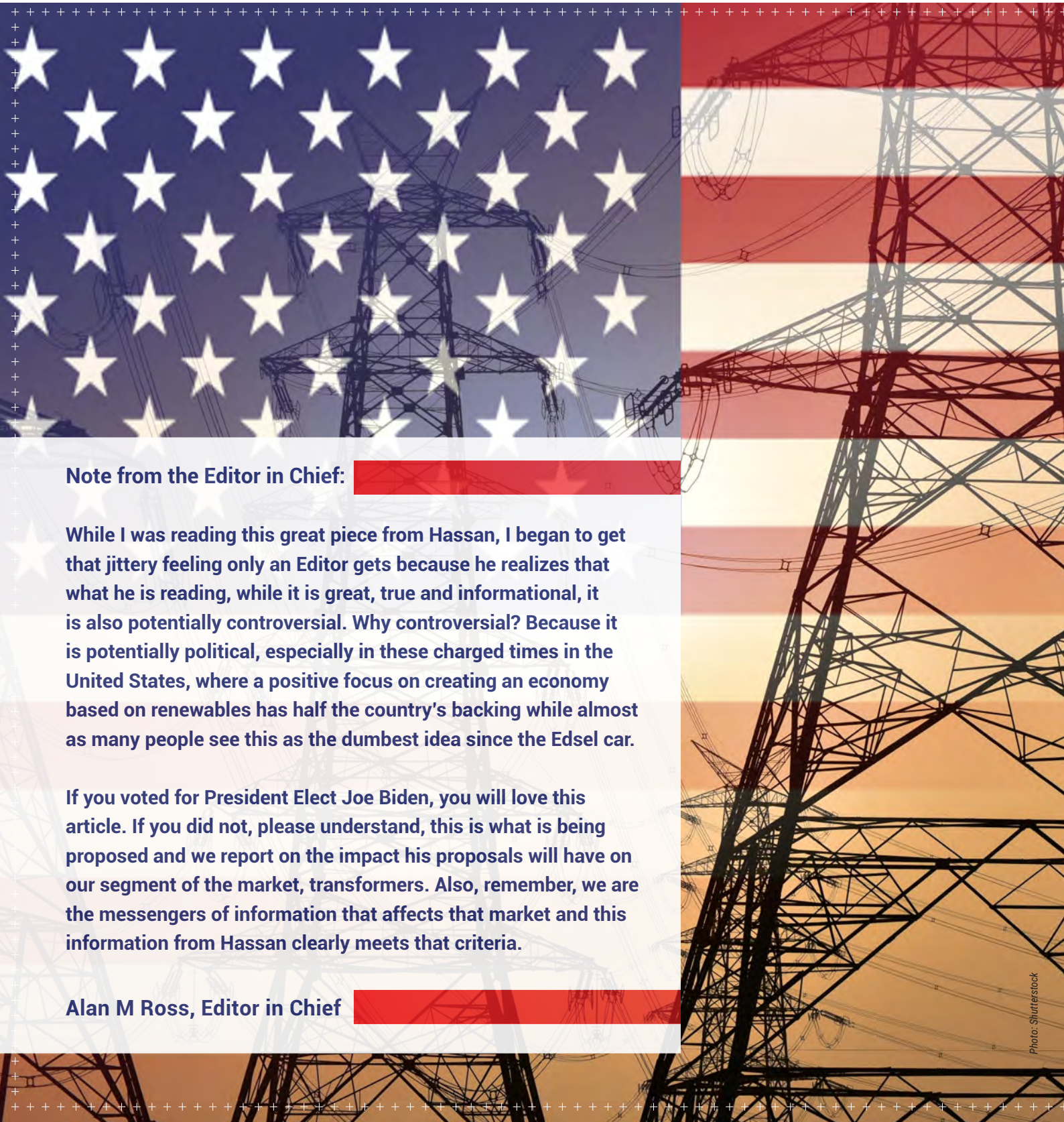
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Impact of US Elections on Global Energy Market

by Hassan Zaheer
powertechresearch.com



Note from the Editor in Chief:

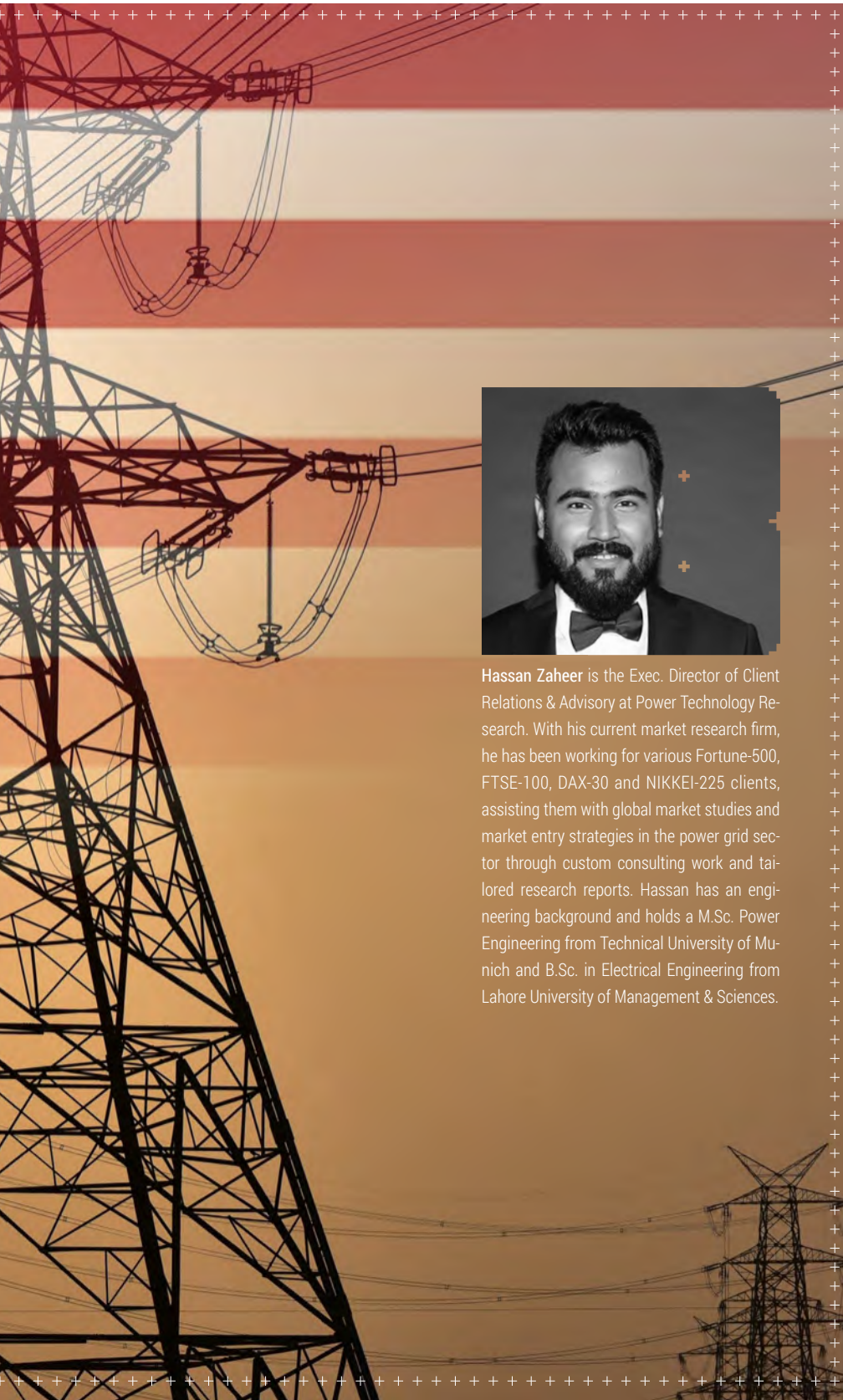
While I was reading this great piece from Hassan, I began to get that jittery feeling only an Editor gets because he realizes that what he is reading, while it is great, true and informational, it is also potentially controversial. Why controversial? Because it is potentially political, especially in these charged times in the United States, where a positive focus on creating an economy based on renewables has half the country's backing while almost as many people see this as the dumbest idea since the Edsel car.

If you voted for President Elect Joe Biden, you will love this article. If you did not, please understand, this is what is being proposed and we report on the impact his proposals will have on our segment of the market, transformers. Also, remember, we are the messengers of information that affects that market and this information from Hassan clearly meets that criteria.

Alan M Ross, Editor in Chief

Biden is expected to revert to Obama-Biden Administration era policy and retain the status of large power transformers (LPTs) as strategic assets.

Joe Biden, a Democrat, is the apparent winner of the U.S. presidential race as a result of elections held on November 3, 2020. Recent elections are expected to have a considerable impact on the energy sector not only in the U.S. but globally as well, which we will discuss in this article.



Hassan Zaheer is the Exec. Director of Client Relations & Advisory at Power Technology Research. With his current market research firm, he has been working for various Fortune-500, FTSE-100, DAX-30 and NIKKEI-225 clients, assisting them with global market studies and market entry strategies in the power grid sector through custom consulting work and tailored research reports. Hassan has an engineering background and holds a M.Sc. Power Engineering from Technical University of Munich and B.Sc. in Electrical Engineering from Lahore University of Management & Sciences.

Paris Climate Agreement

Biden will rejoin the Paris Agreement, which is the most inclusive global agreement on climate change to date. Unlike the Kyoto Protocol, which focused on cutting emissions from the developed world, this agreement sets a goal to which almost every country in the world has agreed to contribute. The goal set in the Paris Agreement is to keep a global temperature rise in this century to below 2°C above pre-industrial levels. Each country will determine their own Nationally Determined Contributions (NDC) and will report their progress. Every 5 years there will be a global stock take. Support is provided through finance, including the Green Climate Fund (GCF), to developing and the most vulnerable countries to help them reach their own national objectives.

In 2017, the U.S. under Trump's administration withdrew from implementing all non-binding clauses of the Paris Agreement. Citing costs to the taxpayer and claiming the deal was inherently unjust, he halted the NDC and the GCF. Followed by the withdrawal, the U.S. formally withdrew from the Paris Climate Agreement on November 4, 2020. Taking cues from the Trump administration, other countries had already envisioned the agreement without the U.S. and started discussing plan B, which requires China and India, the number 1 and number 3 major carbon emitters in the world, to step up their commitments. In 2019, the European Union held meetings to confirm these commitments. China and India are developing countries which are not obligated to cut emissions as per the U.S, but they agreed to cut their greenhouse gas emissions under the Paris Agreement.

Had Biden lost the elections, it would have been difficult to save the Paris Agreement since the onus would have fallen on other industrialized countries to push emerging economies to cut emissions. As the U.S. rejoins, there will have to be new targets made. Currently, the Paris Agreement has set a target for 2030 of 40% cuts in greenhouse gas emissions (from 1990 levels), but with the last years of inaction it will be harder for the U.S. to hit those targets.

Clean Energy Revolution and Environmental Justice (The Biden Plan)

The Biden Plan covers many aspects of the environment, including the protection of biodiversity and wildlife refuges, ensuring access to clean drinking water and producing cleaner energy. Capital for the plan will come from rolling back Trump tax incentives and will require the federal government to invest \$1.7 trillion over the next ten years. This amount, coupled with additional private sector, state and local investments, will total to more than \$5 trillion. The five major points of the plan are as follows:

- Ensuring that the U.S. achieves 100% clean energy economy and net zero emissions by 2050;
- Building a stronger, more resilient nation;
- Rally the rest of the world to meet the threat of climate change;
- Stand up to the abuse of power by polluters who disproportionately harm communities of color and low income;
- Fulfill obligations to workers and communities who powered the industrial revolution.

1. Ensuring that the U.S. achieves 100% clean energy economy and net zero emissions by 2050

On the very first day, President Biden will sign a series of executive orders that will go beyond Obama-Biden administration to offset the effects of the Trump presidency. Biden's first day plan includes the following:

- Require aggressive methane pollution limits for new and existing oil/gas operations;
- Employ a federal government procurement system (which



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annually spends \$500 billion) to push 100% clean energy and Zero Emission Vehicles (ZEVs);

- Make all U.S. government installations, buildings and facilities more efficient and climate ready;
- Reduce greenhouse emissions from the transportation sector, which happens to be the fastest growing source of U.S. climate pollution - this will be carried out by enforcing the existing Clean Air Act and introducing extensive fuel economy standards, 100% of new sales for light/medium duty

vehicles will be electrified and there will be a yearly improvement of the fuel economy in heavy-duty vehicles;

- Include advanced biofuels which will make agriculture a part of the climate change solution;
- Introduce aggressive appliance and building efficiency standards to save consumers money and reduce emissions;
- Require public companies to disclose climate risks and greenhouse emissions from their operations supply chains;

- Every federal infrastructure investment should reduce climate pollution and consider the effects of greenhouse gas emissions and climate change.

Biden's legislative agenda on climate change will establish a mechanism to enforce the net-zero emission targets no later than 2050.

Following the Executive Orders, Biden's legislative agenda on climate change will establish a mechanism to enforce the net-zero emission targets no later than 2050, but will also include a target for 2025 (which is the end of his term). This will be done through investments in energy, climate research and innovation and resilient infrastructure. The plan will:

- Invest \$400 billion over ten years to create industries with a focus on clean energy research and innovation - Biden will create ARPA-C, a new, cross-agency Advanced Research Projects Agency bringing together top talent to focus on achieving America's clean energy targets;
- Incentivize deployment of clean energy on fast track across the country especially in areas affected by climate change;
- Establish grid scale storage at 1/10th of the cost of lithium-ion batteries;
- Shift to small modular nuclear reactors at half the cost of today's reactors;
- Move refrigeration and air conditioning to use refrigerants with no global warming implications;
- Net-zero energy buildings at net-zero cost;



- Employ renewables to produce carbon free hydrogen at the same cost as that from shale gas;
- Decarbonize industrial heat that comes from the manufacture of steel, concrete, chemicals and reimagining carbon neutral construction materials;
- Leverage the food and agriculture sector to remove CO₂ from the air and store it underground;
- Capture CO₂ from the powerplant exhausts, store it deep underground and utilize it to make alternative products;
- Aviation constitutes nearly 2% of global gas emissions - one year agenda aims to target greenhouse aviation emissions;
- Accelerate the development and deployment of carbon capture sequestration technology;
- Identify the future of nuclear energy to tackle climate emergency.

The Biden plan will incentivize the deployment of clean technology throughout the economy to achieve aggressive emission reductions. Here are a few highlights:

- Improvement in energy efficiency of buildings - Biden will build on his efforts on 'Recovery Act' and will set a target of reducing the carbon footprint of the U.S. building stock by 50% by 2035, introducing incentives for deep retrofits combining appliance electrification, efficiency, and on site clean power generation;
- Accelerating the deployment of electric vehicles (EVs) and electric vehicle supply equipment - Biden will work with city and state governments to deploy more than 500,000 new public charging outlets by the end of 2030; Biden will restore the full electric vehicle tax credit to incentivize the purchase of EVs;
- Empower local communities to develop alternative transportation solutions that are cleaner;

- Partner with farmers and ranchers for better agriculture practices and deployment of digesters that generate new sources of revenues;
- Migrate the climate impact of urban sprawl;
- Enact a national strategy to develop a low-carbon manufacturing sector in every state.

2. Building a stronger, more resilient nation

President-elect Biden notes that infrastructure is critical to economic growth and as part of his plan:

- Improve and design common-sense zoning and building codes;
- Work with the insurance industry to lower costs to customers;
- Coastal restoration and

reinforcement of roads, bridges;

- Railroad expansion of both passenger rail and freight.

3. Rally the rest of the world to meet the threat of climate change

Biden is expected to rally the world to meet the emissions targets. The U.S. is the second largest emitter of carbon in the world, but it accounts for 15% of the global emissions, so to really address the climate threat, other countries must be involved, it has to be resolved globally. Under the Paris Agreement, as mentioned earlier, developing countries are not obligated to cut emissions but the U.S. can directly engage the leaders of these nations and persuade them to make national pledges. Through the Trump presidency, that pressure faded but it is expected that the world's



largest economy will again influence the largest polluters to fulfill their commitments. Climate change will be fully integrated into the country's foreign and national security policy, as well as trade.

In his first one hundred days in office, Biden will also demand a worldwide ban on fossil fuel subsidies and also:

- Pursue a global moratorium on offshore drilling in the Arctic and reestablish climate change as a priority for the Arctic Council; he will also use the council to spotlight Russia's activities in the Arctic;
- Ratify the Kigali Amendment to the Montreal Protocol that reduces the use of hydrofluorocarbons;
- Make future bilateral U.S. - China

agreements on carbon mitigation, stop China from subsidizing coal exports and outsourcing carbon pollution - through its massive Belt and Road Initiative Beijing is financing dirty fossil fuel energy projects across Asia and beyond;

- Seek a G20 commitment to end all export finance subsidies of high carbon projects;
- Promote transitions to clean energy with a focus on the Caribbean and Northern Triangle of Central America;
- Create an integrated grid from Mexico through Central America and Colombia, supplied by clean energy.

Transatlantic Relations

The tone in transatlantic relationship is expected to change overnight as

Biden takes charge of the Oval Office in January next year. An immediate return to the Paris Climate Accord will consolidate the good mood. There is a consensus across party lines in the U.S. that China is a rival, but there are countries in Europe that do not see it that way. The biggest hurdle for Biden who intends to rally for an allied front comprising European democracies to curtail China's growing influence Internationally will be Germany which has strong ties with Beijing.

Although Biden will not embarrass European allies as was done in the Trump administration, he will not back down from the pledge that NATO countries gave in 2014 to move towards spending up to 2% of GDP on defense.

The U.S. is the second largest emitter of carbon in the world, but it accounts for 15% of the global emissions.

U.S. administration will expect the Europeans to lead the effort in the continent to counter Russian and Chinese attempts to establish influence as its geopolitical focus shifts towards Asia from Europe and Middle East.

Both Biden and Europeans are likely to make another attempt towards a transatlantic free trade agreement.

Bulk Power Executive Order

Biden is expected to revert to Obama-Biden Administration era policy and retain the status of large power transformers (LPTs) as strategic assets. The import of LPTs from China is expected to stay at the current level, while rally countries like Canada, Mexico and South Korea may get a break from that ban as United States' local manufacturing capability builds over time to meet local requirements.



4. Stand up to the abuse of power by polluters, who disproportionately harm communities of color and low-income

According to Biden, everyone feels the effects of climate change, but the impacts on health, economics and quality of life are felt more acutely in communities of color, low-income, and in tribal lands. Biden will direct his EPA and the Justice Department

to pursue cases to the fullest extent permitted by the law and if needed, corporate executives will be held personally accountable and this could include jail time.

The plan will ensure that all communities have access to safe drinking water. Not only is there insufficient water in certain regions, but monitoring of lead and other contaminants is necessary to eliminate health risks. In addition,

much of the infrastructure is very old and will need to be updated or replaced.

5. Fulfill obligations to workers and communities who powered the industrial revolution

Biden will fulfill the obligations to all workers impacted by the energy transition, like coal miners and power plant workers and their communities.



Conclusion

The success of Biden's agenda rests with his ability to legislate through Congress and specifically the Senate. After the election, the Republicans have 50 senators, and the Democrats have 46. Two senators, representing other parties, usually side with the Democrats, but the fate of the Senate still hangs in balance until the Georgia run-off elections in the first week of January.

If Democrats win both seats, then it will be a 50-50 split in the senate and the Vice President has the power to cast the tie-breaking vote. This will clear the way for Biden to fully implement his agenda and not just rely on executive powers which are limited in their scope.

Regardless of the federal government, it is interesting to note that polls of the American people show a high level of support for the

Paris Climate Agreement and 160 U.S. mayors and several states have promised to honor the agreement. It is also worth noting that, while the federal government has not led the country in clean energy, 29 states have adopted the Renewable Portfolio Standards which mandate that a specific portion of electricity that utilities sell come from renewables. 14 states have adopted California's clean air laws and ten have the same ZEV standards.



**TRANSFORMER
TECHNOLOGY^{COMM}**

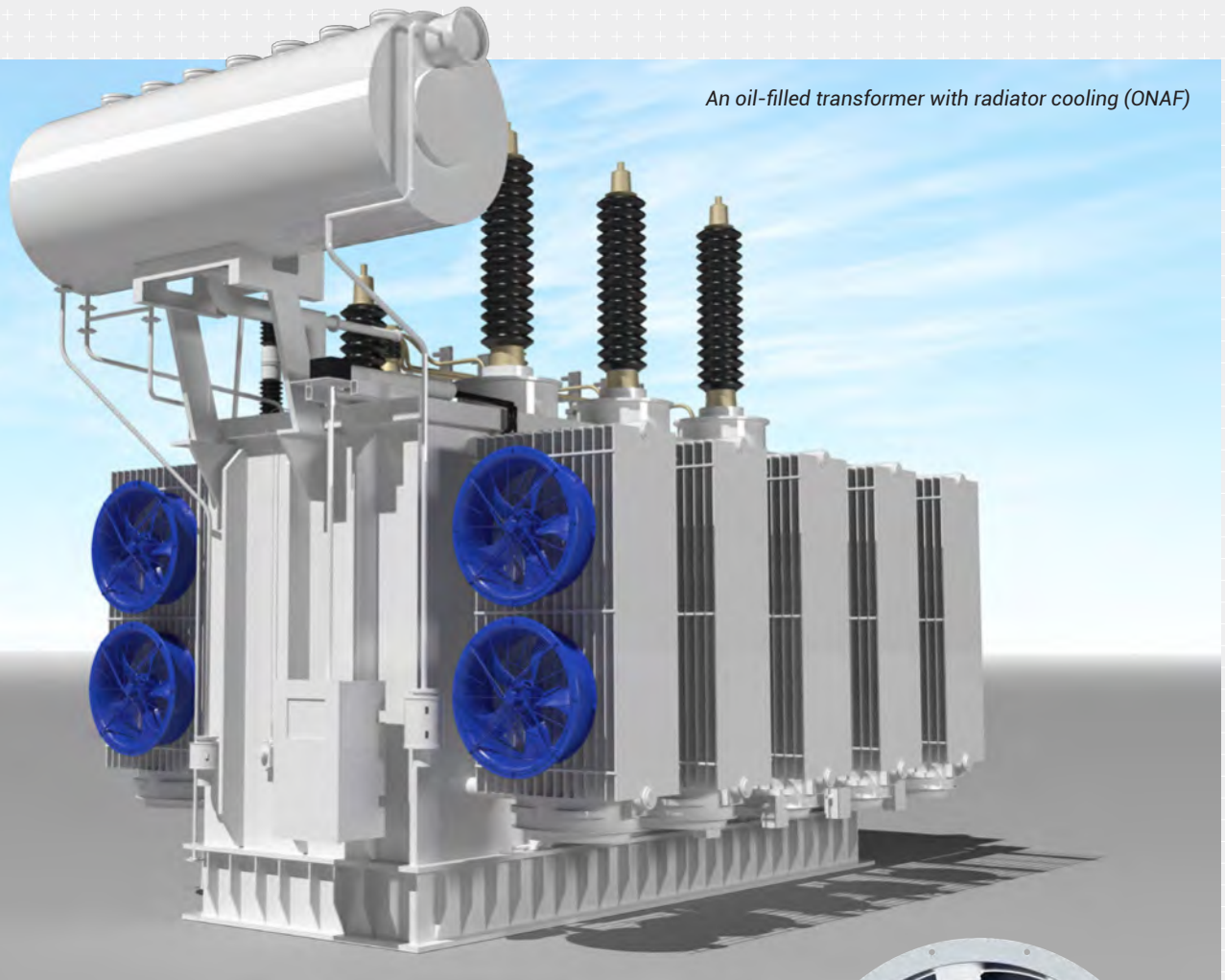
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An oil-filled transformer with radiator cooling (ONAF)

ZIEHL-ABEGG 

**AXIAL
FANS**

**FOR RELIABLE
TRANSFORMER
COOLING**



Cooling is of vital importance for increased service life and operational reliability of power transformers.

Axial fans from German fan manufacturer Ziehl-Abegg have been used to efficiently and reliably cool transformers for over 50 years.

As with any technical system, performance losses can occur during the operation of power transformers. These occur primarily because of the heat generated by the transformer windings. If the winding becomes seriously overheated – something that typically occurs in the event of an overload – the transformer must be switched off. In the worst-case scenario, this can lead to a blackout. Even a short power outage can cause significant operational as well as financial issues. In a 2013 study, the Hamburg Institute of International Economics found that just a one-hour power outage during lunchtime in Berlin would have a negative economic impact of approximately €22.74 million [1].

However, it is not just short-term overheating that poses a problem. As the guide on loads of oil-filled power transformers (IEC 60076-7) and studies by the University of Stuttgart show, the anticipated service life of a transformer is halved if the temperature at the hottest section of the winding, commonly called the winding hot-spot, rises by just 6 kelvins. Safe and reliable cooling is therefore a fundamentally necessary measure. This is reinforced by current global trends such as rising ambient temperatures and more dynamic load profiles seen with the larger usage of renewable energies.



Aeroacoustic testing of a radiator in the InVent

Basic principles of transformer cooling

In an oil-filled transformer, the oil serves two purposes as an insulating medium and a cooling medium. At a first glance, the cooling of such transformers looks to be an easy task. The hot insulating oil at "top-oil" temperature flows by natural convection into a radiator where the large radiator surface causes the oil to cool through radiation and air convection. The cooled oil then flows back into the holding tank at a "bottom-oil" temperature. ONAN (Oil Natural Air Natural) is the name given to transformers with this "natural" oil-air cooling circuit.

However, at high power density or high ambient temperatures, the natural cooling of ONAN transformers is no longer sufficient. The simplest way to improve the cooling performance is to increase the natural air cooling with the help of greater air flow using fans. This air-forced cooling is the reason for the name given to these transformers, ONAF (Oil Natural Air Forced).

Reliable transformer cooling using fans

The cooling performance of the ONAF cooling system depends on the local air and oil flow conditions in the radiator and the resultant local temperatures and mass flows. This understanding of the system is essential in order to guarantee efficient, quiet and reliable cooling, and requires collaboration between transformer and fan manufacturers. Axial fans from German fan manufacturer Ziehl-Abegg have been used in ONAF transformers for more than 50 years. With Ziehl-Abegg's free online software program "FANselect", transformer manufacturers can input their specific system requirements and the appropriate fans will be selected.

The data shown in the "FANselect" program is from Ziehl-Abegg's state-of-the-art development center, "InVent." The development center houses the world's largest combined test chamber in which air performance (volume flow and increase in static pressure), electrical power consumption and fan acoustics are accurately measured at the same time:

- * Air performance in accordance with DIN 24166 in accuracy class 1 and AMCA 210
- * Sound power data in accordance with DIN 3745 in accuracy class 1 (type A) and ISO 13347

This testing system is also TÜV and AMCA certified, providing transformer manufacturers with reliable data so they can create the cooling system required.

Axial fans from Ziehl-Abegg have been used to efficiently and reliably cool transformers for over 50 years.



Trials and testing using market standard radiators are conducted in the world's largest combined test chamber for fans – InVent. The knowledge gained from this, such as pressure loss or radiator impact, can be used by manufacturers to optimise their own product.



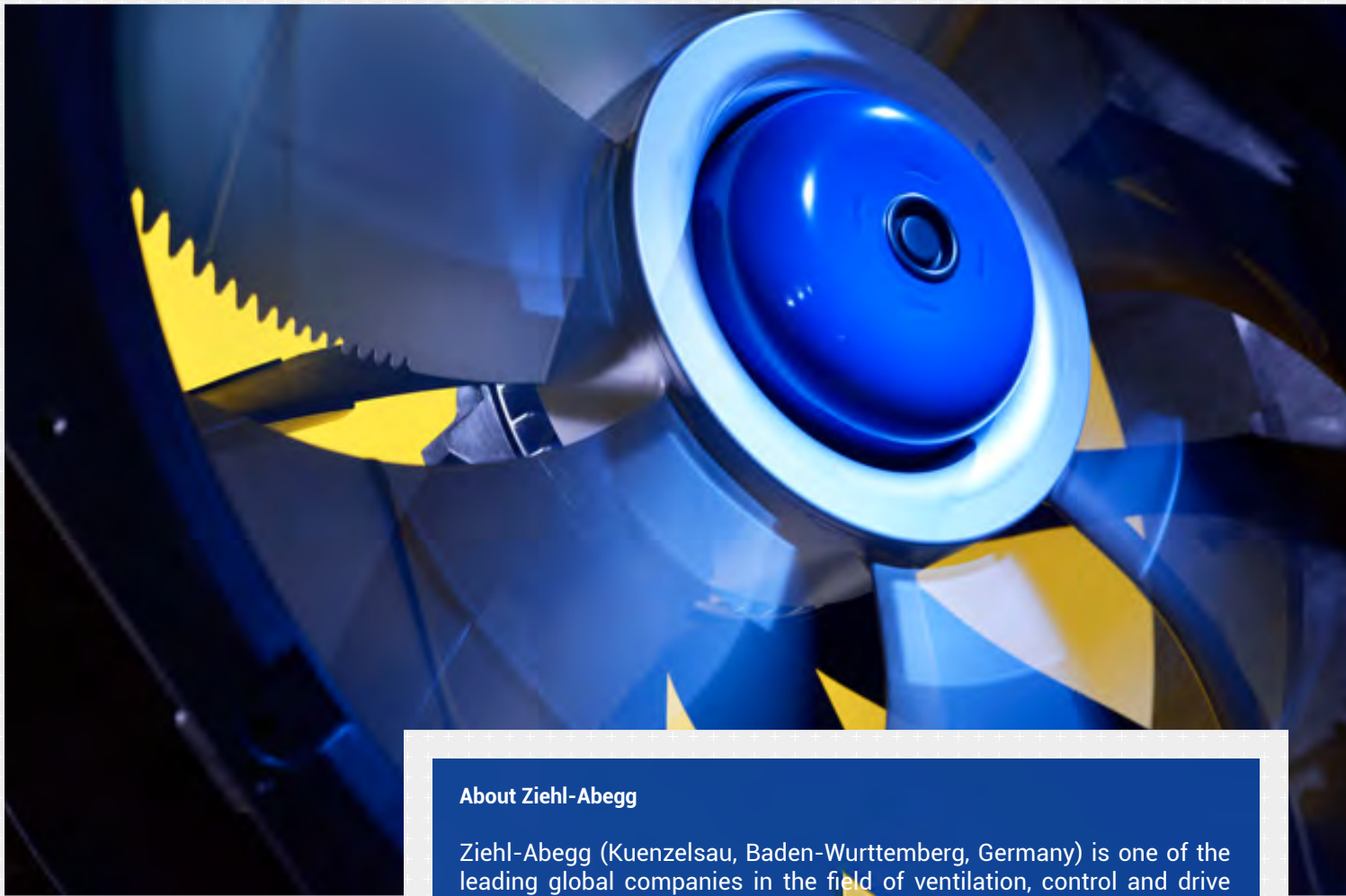
The "FANselect" program provides realistic fan data which has been measured with the actual fan housing or nozzle used, as well as the required guard grilles. This specific data is of particular relevance when giving details on sound emissions, which is especially important for transformer installations as they are often located near residential areas.

Axial fans from Ziehl-Abegg have been designed to reduce sound emissions. In the FE2owlet fan, engineers used knowledge acquired from the near silent flight of a barn owl to design the shape of the impeller blades. Another fan model, the ZAplus, has corrosion-free fan housing that enables the cooling performance to be improved while keeping sound emissions extremely low. This is achieved through a 3-dimensional, flow-optimized housing geometry, already in common use in turbine technology and which was first used in fans by Ziehl-Abegg.

Today, transformer cooling primarily uses AC fans with an asynchronous motor as a drive unit. With the growing trend of digitalization, electronically commutated motors (EC motors) are increasingly being used as well. Ziehl-Abegg has seen a rise in selections using the ECblue fan, a well-established product in cooling technology for many years. The ECblue design uses an energy-saving and speed-adjustable permanent magnet motor with integrated motor electronics. This enables the cooling fan to be easily integrated into the digitalization of transformers, resulting in very precise oil temperature control through speed adjustment. Current oil temperatures as well as dynamic load changes can be monitored to avoid overheating at the hot spot. The ECblue also offers advanced communication options: internal fan data can be read out, displayed, and documented in the overarching monitoring and surveillance system.



For more than 100 years Ziehl-Abegg has produced fans for outdoor use in various climates and environmental conditions around the globe. This experience is relied upon to develop reliable and durable axial fans to be used for transformer cooling. These fans provide safe, long-term cooling to ensure that transformers remain in continuous operation, while also lowering electricity costs and reducing CO₂ emission and sound emission levels to a minimum. All these factors are key to providing safe and reliable transformer cooling.



About Ziehl-Abegg

Ziehl-Abegg (Kuenzelsau, Baden-Wurttemberg, Germany) is one of the leading global companies in the field of ventilation, control and drive technology. In the 1950s, Ziehl-Abegg established the basis for modern fan drives: external rotor motors which even today are still seen as state-of-the-art worldwide. Another area of business is electric motors which provide the power, for example, for elevators, medical applications (computer tomography equipment) or deep-sea underwater vehicles. The theme of electro-mobility for motor vehicles was established as part of the Ziehl-Abegg Automotive Team in 2012.

The high-tech company has an impressive innovative capability. Ziehl-Abegg employs 2,400 personnel in its production plants in Southern Germany. The company has a global workforce of 4,300 spread between 16 production plants, 29 companies and 113 sales locations. The products, approx. 30,000 in all, are sold in more than 100 countries. Turnover totals 633 million euros, with exports accounting for three quarters of the figure, (all numbers refer to the year 2019).

Emil Ziehl founded the company in Berlin in 1910 as a manufacturer of electric motors. After World War II the company's headquarters were relocated to Southern Germany. Ziehl-Abegg SE is not a listed company but instead is family-owned.

For more information visit www.ziehl-abegg.com.



ZIEHL-ABEGG 

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GO TRADITIONAL
OR ALTERNATIVE?

Traditional Transformer Oil vs. Today's Alternative Fluids

by **Mark Stone**
+++++

Today, most transformers are filled with mineral oil. This has been the case since the late 19th century, when chemist Elihu Thomson, whose company later merged to form General Electric, patented the use of mineral oil in transformers to help disperse heat from the core of a transformer in order to prolong its life. Presently, alternative fluids are becoming more and more popular as we look for options that further prolong transformer life, lower environmental risks, and save money.

What makes these new natural and synthetic fluids so popular?

There are a small handful of companies that make natural and synthetic esters, including Cargill, ABB, M&I Materials and GE Prolec, to name a few. By far, one of the most popular alternative fluids in today's market is Cargill's FR3. One of the biggest drivers behind the popularity of FR3 and other natural and synthetic esters is the fluid's high flash point (330°C) and fire point (360°C). This is more than double what mineral oil filled transformers can stand, making them great fluids for both indoor and outdoor transformer placement.

Another factor driving popularity is their biodegradability. Biodegradable fluids are more suitable for sensitive areas like dams and any property close to water. By choosing these fluids, you will avoid investing large sums of money on containment structures to hold 110% of nameplate gallons. Environmentally speaking, because these fluids are biodegradable, leaks or failures of units will have a much lower environmental impact than what we see with traditional transformer fluid. FR3, for example, contains no petroleum, halogens, silicones, or

sulfurs, making the cleanup easier and less expensive than that of typical transformer mineral oils. As a result, this type of fluid is very desirable to insurance companies. For example, companies like FM Global are offering incentives and encouraging some industrial manufacturers to retrofit or replace all their oil filled units with these high fire point, less flammable, natural or synthetic ester fluids.

What about reliability?

Reliability is very important in today's electrical energy industry. Natural and synthetic esters are very stable fluids and have a greater cooling capacity than the high-molecular-weight silicone fluids and hydrocarbon dielectric fluids, adding to their desirability. Transformers with thermally upgraded paper and FR3 take about eight times longer to reach end of life criteria than a mineral oil filled transformer.




Mark Stone has 34 years of experience in the electrical distribution and testing industry, specializing in all types and sizes of transformers, from sampling and testing to repairs and maintenance. In his current role as Training Manager at Southwest Electric Co., Mark works to develop, coordinate, and implement training and drive continuous improvement programs with an emphasis on identifying the needs of current & future staff development to ensure standards of quality and safety across divisions.

Oil testing process

The testing of FR3 is similar to the way mineral oil is tested – by pulling a good representative sample from the bottom valve of the transformer. The difference is more about the interpretation of the results than the tests themselves. To maximize the life of natural and synthetic ester fluid transformers, the units need to be maintained at low oxygen levels and low moisture levels, just like mineral oil filled transformers.



Photo: Shutterstock



Over the years, the transformer industry has seen little change. The shift in fluids is one of the bigger changes we have seen in years, and everyone is extremely interested in learning as much as they possibly can about these natural and synthetic ester fluids.



One of the biggest drivers behind the popularity of FR3 and other natural and synthetic esters is the fluid's high flash point (330°C) and fire point (360°C), which is more than double what mineral oil filled transformers can stand.

Gassing

During the first few years, natural esters will generate small amounts of ethane (C_2H_6 ; around 200 to 300 ppm), which is caused by the stray gassing that naturally occurs with these natural ester fluids. This is not an indicator of a localized hot spot in the transformer. The C_2H_6 emissions should level off after a few years.

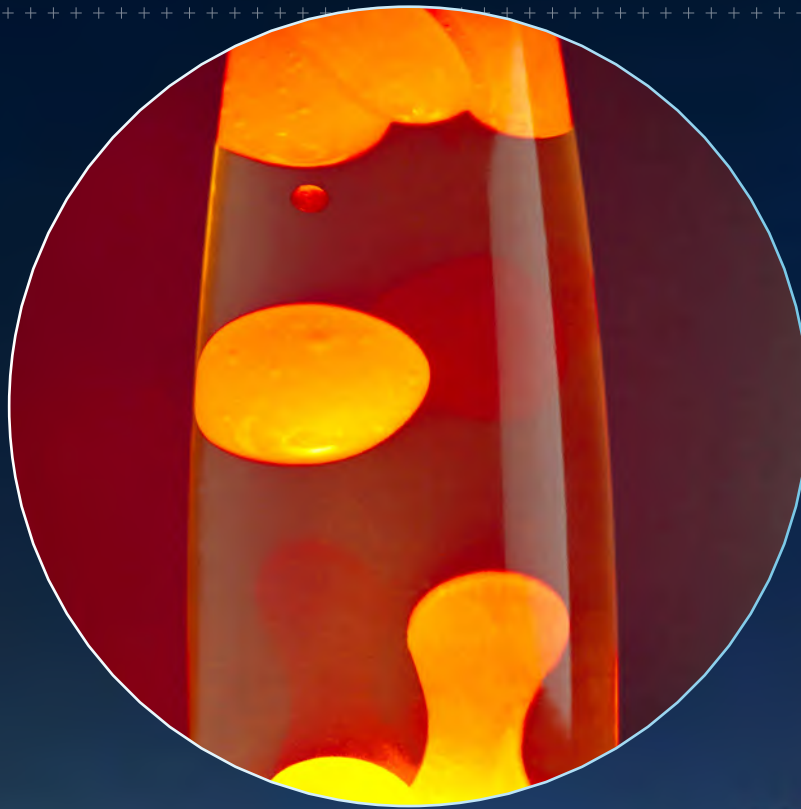
Moisture content

One of the biggest enemies to the solid insulation in the transformer is water. Natural and synthetic ester fluids will hold more moisture in the fluid and less moisture in the paper as compared to mineral oil filled transformers, helping to keep the most important part of the transformer, the solid insulation, dry. For instance, at about room temperature, mineral oil will hold approximately 50 ppm, whereas FR3 will hold around 1000 ppm. If you have a high moisture content in your ester fluid filled transformer, the ester fluids will generate acids. These weak, long-chain fatty acids react to form new ester links that put a protective layer over the solid insulation, protecting it from future decay. In oil filled transformers, the oil does not help keep the paper dry. As a matter of fact, the paper can hold hundreds or even thousands of times more moisture than the oil, which results in a very long and drawn out process to dry an oil filled transformer in the field.

Can an oil filled transformer be retro-filled with natural ester fluid?

Extensive lab testing and field work confirmed that transformers filled with mineral oil and high temperature hydrocarbon fluids (R-Temp) can be retrofilled with natural ester fluids. Performing the retrofill can help slow the transformer aging process, lower the environmental risk, and improve the short-term capability to overload the transformer.

Before you begin, there are a few things you should know. The biggest issue with retrofilling an oil filled unit with FR3 is the draining process. You will never get 100% of nameplate gallons out of the transformer because the winding, core, paper, and cardboard inside the transformer have been absorbing some of the oil over time. While your transformer is being drained, confirm enough of the original fluid is removed from the windings, or you may lower the fire point to below $300^{\circ}C$, making the



Extensive lab testing and field work confirmed that transformers filled with mineral oil and high temperature hydrocarbon fluids can be retrofilled with natural ester fluids. However, if you are topping off a transformer with a different fluid, you need to make sure the two fluids are compatible.

Mineral oil is still, by far, the most popular fluid for transformers because it is lower in cost and readily available, but is it always going to be available to us?



transformer unacceptable for indoor use. You should also verify that there are no free breathing capabilities by checking that the conservators and nitrogen systems are working properly, and that atmosphere cannot come in contact with the FR3.

Fluid compatibility

Remember that there are quite a few different types of transformer fluids out there, some of which you can no longer purchase. If you have these types of fluids and your transformer develops a leak, you must be very careful when choosing which type of fluid you are going to use to top off your transformer.

Some of these transformer fluids are not compatible with each other. Take silicone for example. While you can still buy silicone, it does not mix well with other fluids. If you top off an oil filled transformer with silicone, the two fluids will not be miscible; the fluids inside your transformer will look like a lava lamp – unmixed. Again, if you are topping off a transformer with a different fluid, make sure the two fluids are compatible.

Conclusion

Over the years, the transformer industry has seen little change. The shift in fluids is one of the bigger changes we have seen in years, and everyone is extremely interested in learning as much as they possibly can about these natural and synthetic ester fluids.

Today, we have many more codes that dictate which type of fluids we can use depending on where we install our transformers (NEC codes, fire prevention codes, etc.). Mineral oil is still, by far, the most popular fluid for transformers because it is lower in cost and readily available, but is it always going to be available to us? Though the change may not be quick, the natural and synthetic ester fluids market is coming on strong. If you do not have a transformer with one of these fluids, you probably will soon.

Managing the Reliability of an Industrial or Commercial Electrical Power System / E 06

by **Chuck Baker**
+++++



Andy
Reliability Manager of
Electrical Power System



Brian
Regional Vice President
(head person for this plant)



Chuck Baker is the President of PowerPro 360, a company offering power system reliability assessment and reliability maintenance programs for Industrial and commercial organizations. Chuck entered the world of Substation and Power System Maintenance 36 years ago and has spent the majority of that career on the operations side of power and distribution system maintenance and the development of power system maintenance programs.

Cast
in the order of appearance:

- Andy** Reliability Manager of Electrical Power System
(recently hired by Brian)
- Brian** Regional Vice President
(head person for Smith Industries plant)



Welcome back and thank you again for continuing to follow the introduction and implementation of the reliability centered maintenance program on the Smith Factory Power System. It's been a tough process, but I am receiving great support and cooperation and I am happy with the progress.

If you recall, a key portion of our foundation power system maintenance strategy is the Arc Flash Study. In the last discussion we had, I said that I would be covering this key component in this edition.

Let me give you a little detail on why we are doing this so quickly after my arrival.

- 1) It is legally required by NEC and OSHA. OSHA is addressing arc flash hazards with required estimations for incident energy. This regulation gives strength to citations and essentially requires an arc flash study be performed. The Standard for Electrical Safety in the Workplace, NFPA 70E, states in Article 130.5 that an arc flash study needs to be reviewed every five years or whenever there is a significant change in the electrical system. The five-year interval is a straightforward requirement... and we are not compliant.
- 2) There are documented instances where OSHA has levied significant fines for non-compliance with arc flash label requirements.
- 3) It is the responsible and safe thing to do for employees and contractor safety.
- 4) It could potentially help avoid unnecessary down time of the distribution system due to design issues.

The other key factor is the incredible information that will be gathered from the arc flash study. I have purchased an asset management program that will take all information from our electrical equipment, from nameplate to service schedule to evaluation of all

inspection reports and testing results. I am going to use the data gathered as a part of the study and load it into this new program.

Let me walk you through what is and has taken place with our study.



The Arc Flash Process

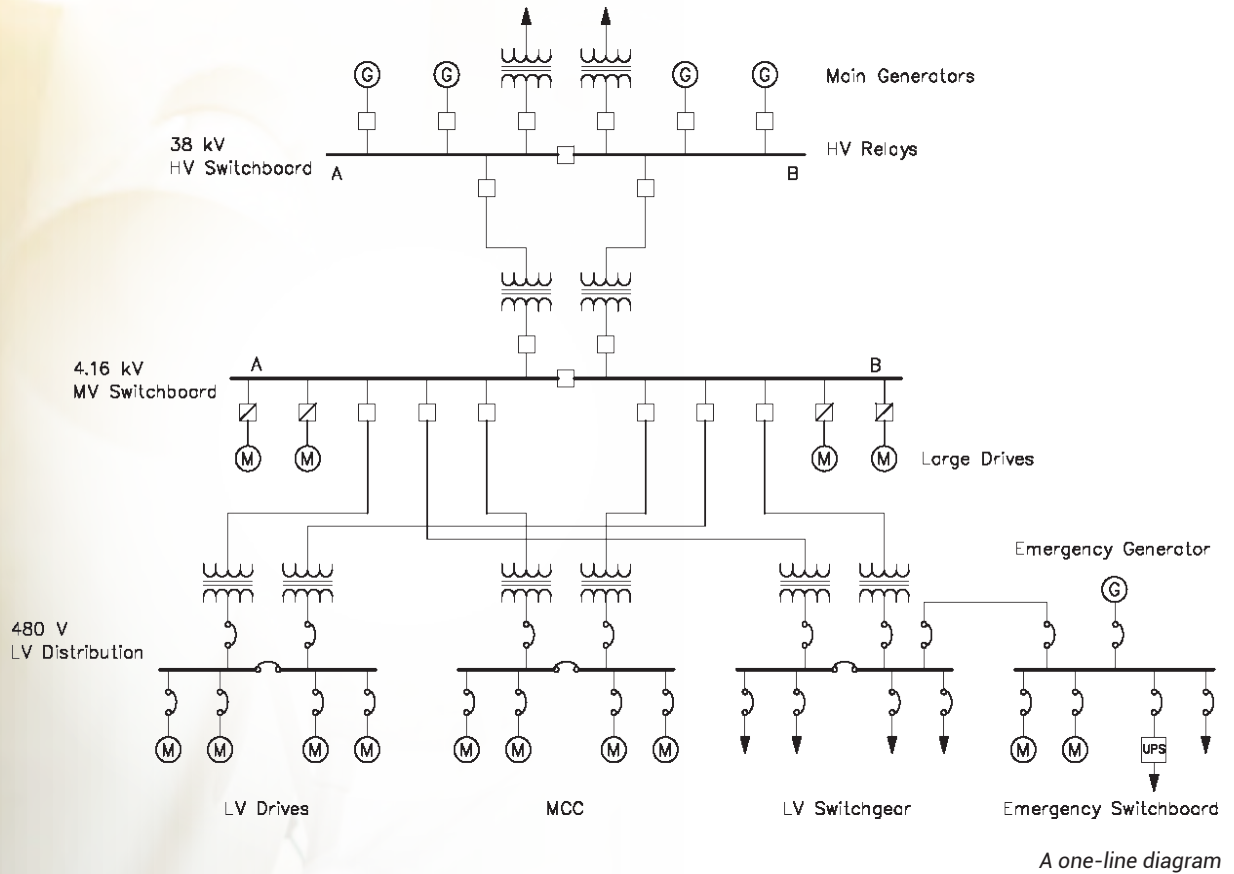
Let me relay the information that was provided by the PE who was performing our Study. He has many years of experience and I think this will help you to understand the process.

A full Arc Flash Study (which is what we require) is a power system analysis of an electrical distribution system for our facility, which consists

of a sequenced series of studies including available fault current calculations, equipment withstand/interrupt rating evaluation, protective device coordination study, and finally an arch flash hazard assessment that incorporates all the information, findings, and adjustments acquired from the previously listed studies.

The process to perform an Arc Flash study begins with the proposal

process. In order to estimate the effort and cost involved in performing an Arc Flash Study, the number of busses in a system must be determined. This is sometimes also referred to as the number of nodes in a system. These nodes can either be calculated nodes or non-calculated nodes. A bus or a node is simply a piece of equipment in a distribution system, especially one that might be worked on while energized, such



are items such as utility grid ties, generators, PV solar arrays, UPS or battery systems, etc. Finally, large motors (over 50 hp) will also need to be identified and quantified for a given system. Once this has all been determined, an estimate can be prepared for the effort and cost involved with the study.

Once the notice to proceed has been given, the first step in the process involves information gathering. This effort includes getting all information on all equipment such as manufacturer and model numbers. It also includes getting all information on each individual breaker, which again includes manufacturer and model along with all trip settings, if applicable. The size and length of all feeder circuits must be obtained as all this information will be used to accurately model the distribution system.

Finally, information must be obtained about the utility service connection by contacting and obtaining available fault current information at the service entrance location from the utility service representative. Detailed information must be obtained about other independent energy sources such as

standalone generators, solar sources, or other alternative energy sources.

This information is now used to construct a detailed model of the distribution system utilizing one of several software packages such as SKM or ETAP. In this model each piece of gear, source, and breaker are entered and modeled using the data and information obtained. If there are multiple sources, the model may need to be created for each scenario to ensure that the worst-case scenario is identified and used in the study. We had an earlier version of a software package and have upgraded to the latest version. In the specification I specified the software we require.

Once the models are complete, the first study that is performed is the **fault current analysis**. This is done using the functionality of the modeling software and it is run for each scenario to determine the worst-case available fault current at each location or bus or node in the system. The equipment evaluation study is done in conjunction with the available fault current analysis to ensure that each protective device in the distribution system is adequately

as switchboards, panelboards, disconnects, starters, etc. Calculated nodes are nodes that a fault current calculation will need to be performed for, while non-calculated nodes will not (likely) require a calculation, but still will need an Arc Flash Label.

In addition to the number of buses or nodes, the number of (independent) power sources needs to be determined and identified in the system. These

rated to interrupt the circuit in the presence of a fault condition. This analysis and evaluation are done using the modeling software such as SKM or ETAP and the available fault current information provided by the local utility company at the service entrance point.

Next, each distribution pathway or feeder from the main service is modeled, and all overcurrent protective devices in each feed are mapped concurrently to examine how these devices will coordinate with each other in the event of an overcurrent situation. The goal is to adjust the settings of the breakers, when possible, to ensure that the overcurrent device closest to the load that is in overload will trip first – so that any unnecessary nuisance tripping further up the line closer to the service entrance is avoided to minimize the outage area in the event of a trip due to overload.

Finally, once all recommended breaker adjustments are approved and implemented, the entire distribution system is modeled to determine incident energy values at each node or bus equipment location, so that an Arc Flash Hazard assessment can be performed. This assessment will determine Arc Flash Boundaries, inside of which personnel working on energized equipment should wear appropriate Personal Protective Equipment (PPE). The incident energy values enable a determination of the appropriate PPE required to be worn

by service personnel according to current standards. The appropriate PPE descriptions will be displayed in the results of the Arc Flash Hazard assessment tables. The calculated incident energies are then used to determine the recommended PPE level category that is associated with each condition. These PPE categories are separated into six possible categories of Dangerous and Levels from 0-4. Equipment classified as Dangerous is beyond the established current PPE protection levels and working on this equipment when energized is extremely dangerous and not recommended.

Level 4 is the most dangerous category that allows for working on energized equipment and requires the greatest amount of PPE protection, which typically results in the service personnel wearing a bee-keeper type suite that is rated to withstand typical arcing faults of this magnitude.

Level 0 is the least dangerous category that requires the minimal amount of PPE when working on energized equipment. Warning labels for equipment are produced so that they clearly identify the current PPE

category, the associated hazards, and the appropriate recommended PPE that should be worn by service personnel when working on the equipment while energized.

If there is equipment that requires a recommended PPE rating of Level 3 or greater, mitigation improvement recommendations will be given to reduce these levels when available. These recommendations will be limited to changes that are typically easy and cost effective to accomplish, such as breaker settings adjustments or fuse replacements. This is another real benefit of this exercise.

Potential Issues or Problems

There are several issues or problems that may be discovered or identified during these types of studies. Some of these issues may include:

- 1) **Insufficient interrupt capability of existing equipment in the presence of the available fault current calculated during the study.** This is an extremely dangerous finding in that it indicates that if a fault condition is encountered, the existing gear may not be able to clear the fault or de-energize the circuit which could result in the injury or death of personnel, and/or serious damage of equipment.
- 2) **Improper coordination of overcurrent protection devices.** This is a problem in that if an overload condition is encountered, there is the potential for a breaker upstream to trip before the more localized breaker trips. This increases the impact scope in the distribution system, which usually increases the impact area of a process.
- 3) **Improper breaker coordination accounting for inrush current in large transformers.** In the device coordination study, the damage



curves and inrush current for each transformer are included in the trip curve analysis for each feeder. If the breaker settings are not set correctly in relation to the transformer characteristics, inrush conditions could cause nuisance tripping. In addition, if transformer damage curves lie inside the trip ratings of related breakers, the transformer could incur damage under certain conditions.

4) Danger to employees working on energized equipment. If there are no labels (or there are incorrect labels) and an employee experiences an arc flash without having on the appropriate PPE, then serious injury or death could occur. This is an enormous legal exposure to the owner as they can be liable if the proper and correct information is not made available to the employee.

5) Code Issues and Safety Issues. Inherent to the studies performed, a code and safety inspections are also conducted, and items notices will be listed for the owner with recommendations to bring this issue into compliance.



Because it has been many years since the last one was performed on this plant, this has been a thorough study with many problems – some potentially fatal – discovered. The vast data on equipment that was generated has been logged into our maintenance program.

The National Fire Protection Association (NFPA) details how to comply with the Occupational Safety and Health Administration's (OSHA) regulation, [29 CFR 1910.333\(a\)](#), through the NFPA 70E standard.

According to the NFPA 70E standard, there are six primary responsibilities that facilities must meet, and these include:

1. Training for employees. We have completed the first round by contracting a training program

vendor and have this training scheduled to repeat as per regulations.

2. Written safety program in place that is actionable.
3. Personal Protective Equipment (PPE) available for employees has been purchased, distributed and they have been trained on utilizing this equipment.
4. Insulated tools.
5. Arc flash hazard degree calculations.
6. Properly labeled equipment.

Arc flash labeling is the responsibility of Smith Industries, not the manufacturer or installer of the equipment. Labeling

is required for any piece of electrical equipment that may need examination, adjustment, service or maintenance while energized, creating the potential for an arc flash incident to occur.

With the information generated from this entire process, Brian relayed to the Executive Management Team what we had completed, why we needed to do this and had a nice overview of the key points. From that meeting we found out that three quarters of the Smith Industry Plants were in fact out of compliance. With the realization that this could take a person's life, the remaining plants initiated their updated study in very short order.

So it is done, we are good for another five years unless we make a significant change in our power distribution study.

Make the Best Start to 2021

At Transformer Technology, we are preparing for a **flying start to 2021!**

We are tremendously excited about the response we are receiving regarding the two big changes to the Transformer Technology Community we've made this year. The first, of course, is that we are no longer just a magazine published four or five times a year but an online, interactive community. However, our magazine roots are as strong or stronger than ever with the move to a monthly focus around a Theme, with additional content on areas we think are a needed focus.

We will begin the New Year with our combined January/February edition that will focus on the theme of **Overheating, Cooling and Creative Solutions**, with additional focus areas on **Testing & Diagnostics, Gages, Radiators, Fans and Monitoring**.

All of you who are interested in being featured in this edition with your case studies, field experiences, solution overviews, company presentations, or as an interviewee, as soon as possible to ensure your spot in the lineup.

In 2020, everyone had to pivot or go out of business. For Transformer Technology, we made a great pivot that will see us thrive in the coming years as we serve our transformer professionals community. In 2021 we are adding strength and creativity to our pivot by focusing on themes that are the areas that you want to hear about and engage in, and that our great contributors can address. Become one of those contributors and give back to the community by becoming an author or interviewee.

Make the best start to 2021!

I look forward to hearing from you,
Alan Ross

THINKING ABOUT STRENGTHENING YOUR POSITION IN THE MARKET?

THINK ABOUT YOUR PRODUCT

THINK ABOUT YOUR COMPETITION

THINK ABOUT YOUR SERVICE

THINK ABOUT YOUR TIME

THINK ABOUT...

DON'T THINK ABOUT MARKETING

LET US DO IT FOR YOU



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