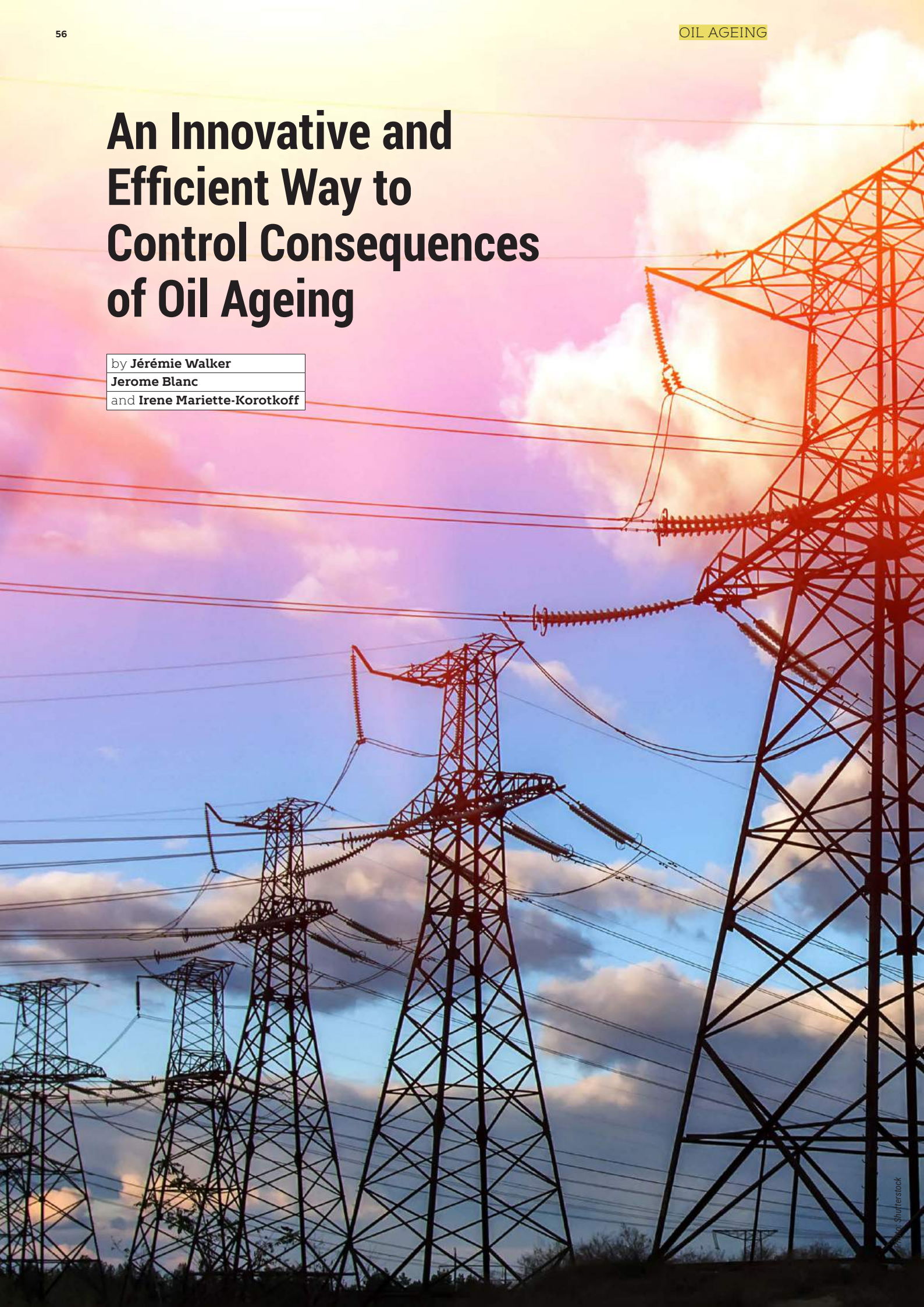


An Innovative and Efficient Way to Control Consequences of Oil Ageing

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Gas accumulation in mineral oil can make partial discharges persistent and lead to transformer explosion, increasing the risk of fire. A gas-evolving mineral oil can become gas absorbing by adding a few percent of methylpolyarylmethane derivatives, a highly efficient additive that can limit the impact of mineral oil decomposition for transformers affected by corona partial discharge.



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Arkema team has more than 30 years of experience in the development and analyses of dielectric and insulating fluids for high voltage capacitors and transformers. Beyond some valuable technical publications made at international events in these fields, they are members of CIGRE and of International Electrotechnical Commissions (IEC) to contribute to the maintenance of standards.

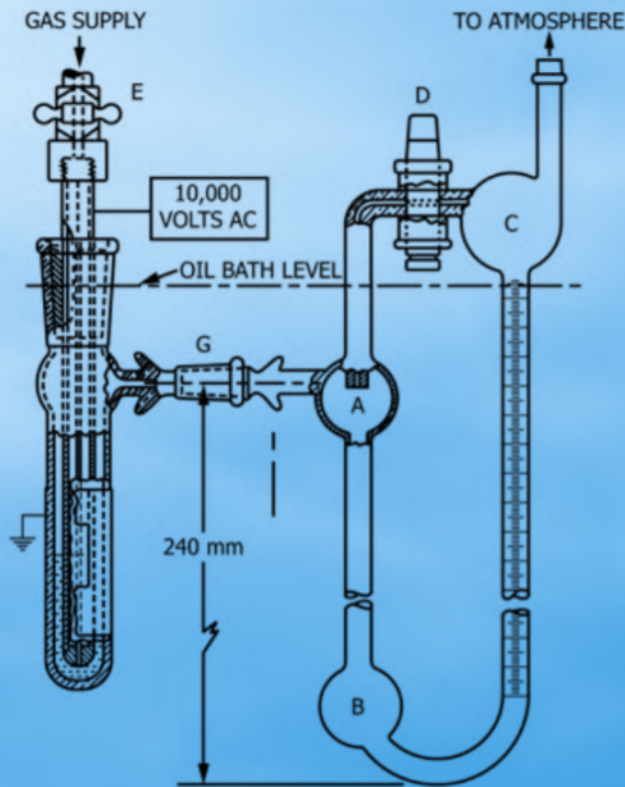


Figure 1. Schematic diagram of gassing-cell and gas-burette assembly (from IEC 60628 [1])

Background

The oil used in transformers has several main functions as it acts as electrical insulation, cooling medium and information carrier. Besides, there are some additional properties expected from transformer oil, such as compatibility with cellulose insulation, fire safety consideration and environmental requirements. Mineral oils have been widely used in transformers for more than a hundred years. However, most mineral oils are now highly refined to meet health and environment requirements as well as more stringent requirements for corrosive sulphur. Highly refined oils usually contain less aromatic and other unsaturated compounds due to the hydrogenation process. Consequently, the gassing tendency of the mineral oils becomes more positive. This phenomenon and a way to deal with it will be described more precisely in this article.

About Gassing Tendency

The gassing tendency refers to the behavior of an insulating liquid when gases have been produced due to low energy electrical stresses.

When the gassing tendency is negative, the gases are absorbed by the oil. When the gassing tendency is positive, more gases are produced than the absorption capacity of the oil.

This concept could be characterized in the following way:

- When the gassing tendency is negative, the gases are absorbed by the oil.
- When the gassing tendency is positive, more gases are produced than the absorption capacity of the oil.

The gassing tendency of transformer insulating fluids under partial discharge conditions has become an increasingly important issue because the presence of gas increases the potential for failure. To ensure a harmonized definition and a reliable measuring method, the gassing tendency of insulating fluids is fully described in IEC standard 60628-A [1].

After being dried and saturated with hydrogen gas, the insulating liquid and the hydrogen pocket above the liquid are subjected in the specific cell to a radial electrical stress under following experimental conditions:

- Voltage: 10 kV
- Frequency: 50 Hz
- Temperature: 80°C
- Test duration: 120 min

During the test, the liquid level in the burette is closely monitored, and the gassing tendency is calculated from the difference between the initial level and the level after 120 min.

A Practical Solution to Solve Positive Gassing

As mentioned above, due to health and environmental issues, mineral oils are almost exempt of aromatic and mainly poly aromatic hydrocarbons (PAH). It is known that the presence of aromatic hydrocarbons has a strong effect on

the negative gassing tendency of the oil. The aromatic species act as hydrogen scavenger if the mineral oil is decomposed due to a partial discharge default of the transformer.

An easy way to cope with this consists in using methylpolyarylmethane derivatives (carrying aromatic rings) as a

complement to mineral oils, in a range of 4 to 8 weight-% in average (and depending on the type and origin of the mineral oil). It will restore the negative gassing performance of the mineral oil.

Methylpolyarylmethane derivatives are available products as they have been extensively used as heat transfer fluids, at service temperatures up to 330°C, thanks to their excellent thermal stability. This use confirms the high stability of this type of molecules. In addition, since methylpolyarylmethane derivatives are synthetic liquids, they have a well-defined composition. Methylpolyarylmethane derivatives are not of the same structure of polyaromatic hydrocarbons, they are

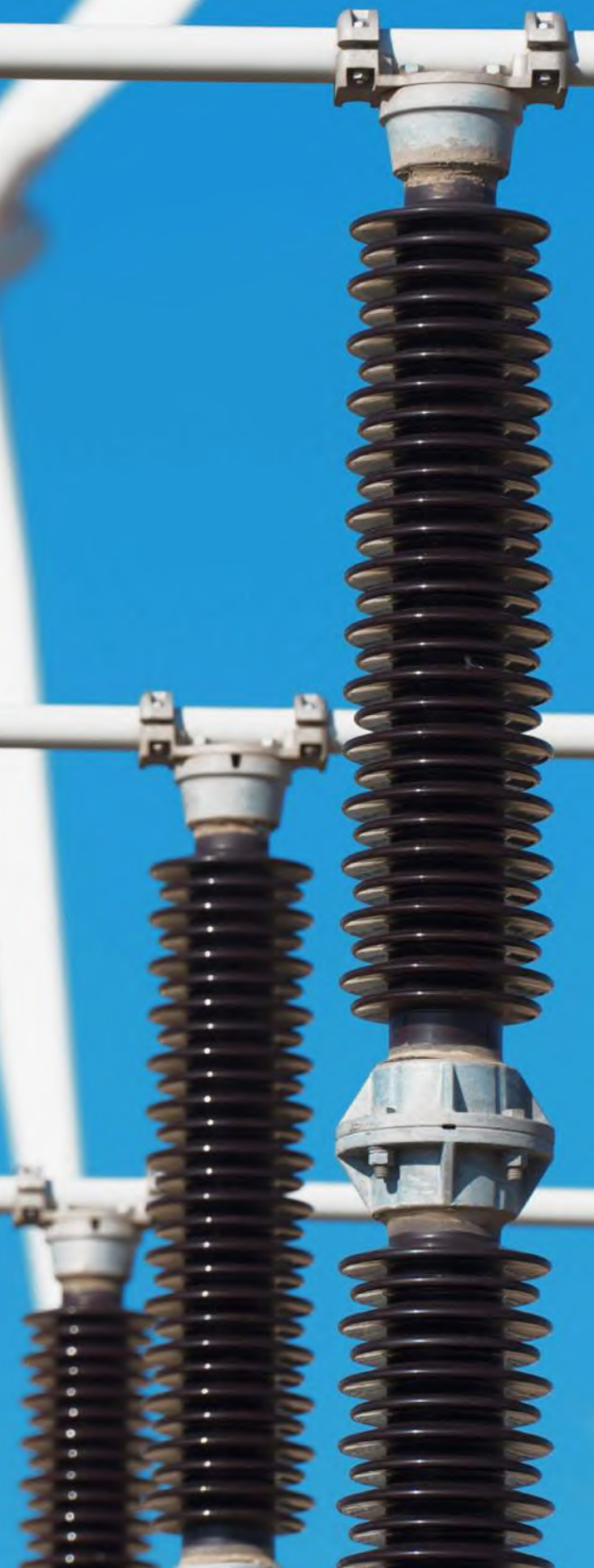


The presence of aromatic hydrocarbons has a strong effect on the negative gassing tendency of the oil.

synthetic molecules obtained by coupling toluene molecules, a widely available raw material, via Friedel-Crafts reactions.

In practice, when a transformer with a corona partial discharge default is detected, several options may be done to solve the problem early enough to prevent it from any risk of fire or explosion. For high voltage transformers, the best-preferred solution is to send back the transformer to the workshop in order to repair the default.

For medium and low voltage transformers, the preferred solution consists in a mineral oil treatment with external tools in order to eliminate maximum of dissolved hydrogen, water traces and other impurities. This treatment is costly and requires a transformer shutdown during a period from one to several days, depending



	Transformer	Power (kVA)	In/Out (kV)	Methylpolyaryl methane derivatives (weight-%)	Gassing tendency mineral oil ($\mu\text{l}/\text{min}$)	Gassing tendency mineral oil with additive ($\mu\text{l}/\text{min}$)
With prior treatment	Case 1	1600	15/0,4	5.6	12.5	-11
	Case 2	500	63/10	6.3	10	-19
	Case 3	2600	34/0,7	8.5	5	-29
Without prior treatment	Case 4	2600	34/0,7	8.5	0	-56
	Case 5	2600	34/0,7	8.5	5	-48
	Case 6	2600	34/0,7	8.5	8	-25

Table 1. Overview of the results for the group of transformers

of transformer size and quantity of oil to treat.

Practical Example

To demonstrate the benefits of the addition of methylpolyarylmethane derivatives in mineral oil of transformers affected by corona partial discharge several studies have been launched over the last years.

First, a series of two transformers underwent a preliminary treatment of the mineral oil in order to remove a maximum of dissolved hydrogen before adding the methylpolyarylmethane additives into the mineral oil.

A second series of four transformers associated with a group of wind turbines were treated by direct addition of the methylpolyarylmethane in the mineral oil already present to the transformer. The oil from these transformers has been monitored and evaluated over several years.

Table 1 summarizes the result obtained on the different transformers.

The amount of methylpolyarylmethane derivatives added was defined by analysis of mineral oil gassing tendency. The target is to reach a gassing tendency in the range of -10 to -20 $\mu\text{l}/\text{min}$ measured for the mineral oil. This target value is

important to have enough negative gassing tendency in the liquid medium to absorb the hydrogen formed due to the corona partial discharge phenomenon.

The oil analyses are done by an external laboratory specialized in transformers oil analysis.

Thanks to their high aromaticity, methylpolyarylmethane derivatives exhibit a strong gas-absorbing ability.

The gassing tendency is measured according to the IEC 60628-A [1], see Table 2.

The trend is similar for all the transformers that received an addition of methylpolyarylmethane oil.

This clearly confirms that the gassing tendency of the transformer oil went from a positive status to a negative status that enables to absorb the hydrogen formed due to the corona partial discharges transformers default.

This comes from the fact that thanks to their high aromaticity, methylpolyarylmethane derivatives exhibit a strong gas-absorbing ability.

For example, according to IEC 60867-1993 standard, it is said to be as low as 130 $\mu\text{l}/\text{min}$ for pure methylpolyarylmethane oils [2].

In the case of oil pretreatment (Cases 1 and 2 in Table 2), the hydrogen increase noticed after few days is normal. During the oil treatment, it is not possible to treat all the oil present in transformer since the oil present in the paper, wood and cardboard is not completely removed. After restarting the transformer this remaining fraction of oil is mixed with the cleaned oil and after few days of operation an equilibrium is reached.

Beyond the positive effect observed for the gassing tendency, it is important to know that the addition of methylpolyarylmethane derivatives does not interfere with other methods to monitor transformer defects. As an example, let's consider thermal defects and the role of dissolved gas analysis (DGA).

Dissolved gas analysis (DGA) is among the most powerful tools for detecting faults in electrical equipment in service. For that reason, DGA analytical techniques and interpretation methods are continuously being investigated and improved. Indeed, to follow the technical trend regarding the increasing use of non-mineral oils (such

as natural and synthetic esters and silicone oils), DGA analytical techniques for non-mineral oils were developed. Among the parameters that needed to be adjusted, time is a critical one. For the extraction of gases dissolved in oil, the viscosity of the oil is a key parameter that needs to be considered to allow sufficient time to reach the equilibrium. The more viscous the oil, the longer the equilibrium time. These parameters are described in the dedicated standard IEC 60567 [3].

Regarding the results, DGA interpretation methods for mineral oils are based on many cases of transformers in service where gas

Comments and Conclusions

The production of gas is the result of the electro-chemical degradation of the fluid into smaller molecules such as hydrogen. In the case of gas-evolving fluid (mineral oil), the gas can accumulate and make partial discharges persistent. The accumulation of the gas could lead to explosion of the transformer and significantly increase the risk of fire to take place. A gas-evolving mineral oil can become gas absorbing by adding a few percent of methylpolyarylmethane derivatives.

The benefits of the methylpolyarylmethane derivatives is their efficiency even if the mineral oil contains some high quantity of dissolved hydrogen. The high efficiency of this additive to limit the

impact of mineral oil decomposition for transformers affected by corona partial discharge phenomenon is important for transformer owners.

In the meantime, other electrical parameters such as breakdown voltage will remain comparable and the addition of this aromatic fraction

will not bring an issue for oil breakdown strength. Moreover, it was proven that the addition of methylpolyarylmethane derivatives does not interfere with the monitoring of other transformer defects such as thermal defects.

The addition of methylpolyarylmethane derivatives does not interfere with monitoring of other defects such as thermal defects.



In addition, the treatment cost will be strongly reduced as it is demonstrated in this article that preliminary oil treatment before additive adding in the transformer is not mandatory.

Based on these interesting results applied to the case of mineral oils in transformers, it would be worth conducting a similar evaluation for transformers filled with vegetable oils and suffering from partial discharge issues.

References

- [1] IEC 60628:1985, Gassing of insulating liquids under electrical stress and ionization
- [2] IEC 60867:1993, Insulating liquids – Specifications for unused liquids based on synthetic aromatic hydrocarbons
- [3] IEC 60567:2011, Oil-filled electrical equipment – Sampling of gases and analysis of free and dissolved gases - Guidance

