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Editorial

High Voltage Insulating Materials—Current State and Prospects

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Progression in the field of insulating materials for power transformers and other high voltage devices is visible regardless of the type of insulation: solid, liquid, or gas. This progression resulted from the necessity of ensuring the proper operation of high-voltage devices. These materials have to ensure correct, continuous, uninterrupted, and safe operation of various devices. It is also extremely important to ensure an appropriate level of environmental safety with the knowledge that high voltage devices and, therefore, insulating materials operate under various stresses, which can be critical during their operation. The in-service conditions require high-quality materials, the properties of which will not change or have small changes over time. Hence, it is very important to investigate the properties of materials used in high-voltage equipment from various perspectives. Thus, electrical (AC, DC, LI, or combined exposure), thermal (e.g., accelerated aging), or chemical (impact of environmental factors or material compatibility) based factors must be taken into account in assessment of these materials. It is the optimal solution that is sought for a given application. Furthermore, the development of the HVDC technology, which involves specific stress conditions and thus specific physical phenomena associated with stress, has become extremely important in this respect.

Since insulating materials are constantly developing and new materials keep appearing in the market (e.g., biodegradable insulating liquids in the case of liquid dielectrics or nano-fluids), this Special Issue is focused mainly on new solutions for the use in high-voltage applications.

The Special Issue "High voltage insulating materials-current state and prospects" has received good responses. From the 21 submissions, 13 were accepted, which gives the rate of acceptance on the level of circa 62%. Among the accepted paper, one is of the review type and twelve are regular papers.

The review paper [1] covers the topic of synthetic ester liquids for transformer applications. It represents a kind of guide for researchers and industrials working with synthetic esters on a daily basis. This paper describes most of the problems concerning the use of the synthetic esters in transformers as an insulating and cooling liquid. The authors presented the fundamental chemical properties of synthetic esters: their AC and DC breakdown voltage; lightning impulse breakdown voltage and pre-breakdown phenomena; synthetic ester-based nanofluids; combined paper-synthetic ester-based insulating systems; application of synthetic esters for retro-filling and drying of mineral oil-immersed transformers; DGA-based diagnosis of synthetic ester-filled transformers; and static electrification of synthetic esters. State of the art analysis indicated the opportunities for synthetic esters. However, the authors also underlined some important challenges for the possible application of the synthetic esters on a larger scale not only in distribution transformers but also in the power transformers of a high level of nominal voltages.

The subject of synthetic esters was also discussed in [2] where the authors proposed a model relating to the drying efficiency of cellulose-based transformer insulation by solely using synthetic esters. The results of the laboratory tests performed by the authors indicated that the drying process is strongly influenced by temperature and time of drying. In turn, the initial level of moisture of the ester has a weak effect on the drying efficiency. The aim of this work was to find the optimal drying conditions on the basis of which a mobile system for the on-site drying of the transformer's insulation will be developed.

The electrostatic charging tendency (ECT) of synthetic ester has been analyzed in [3]. The author also tested the ECT of mixture of synthetic ester and mineral oil. The findings of the author is that the ECT of synthetic ester may be reduced when combined with a small amount (up to 20%) of fresh or aged mineral oil. This result is particularly beneficial when retro-filling power transformers and replacing mineral oil with a synthetic ester.

The ECT of natural ester-mineral oil mixtures is discussed in [4]. It was stated in this paper that there is no clear correlation between the composition of the mixture and the electrification current. Some advantages are visible in the mixture with small amounts of natural ester (up to 10%), which manifested in the reduction in ECT.

The subject of natural ester liquids is continued in the papers [5] and [6]. The first one presents the results of the studies on the electrical behavior of natural ester-based ZnO nanofluids at different concentrations in the range of 0.05–0.4 g/L. The AC voltage based tests indicate that the dielectric strength of natural ester-based ZnO nanofluids increases with the concentration of nanoparticles, with the exception of 0.05 and 0.4 g/L of ZnO. The optimum is reached, however, for 0.1 g/L (for 1% and 10% probability). The authors also conclude that increasing nanoparticles concentration beyond the value of 0.4 g/L reveals the implication of a tunnelling/bridging mechanism that may reduce the value of AC breakdown voltage. In turn, the authors of [6] analyzed the natural ester (Marula Oil) treated with Al_2O_3 with concentrations varying from 0.1 g/L to 2 g/L and 0.25 g/L. They use mathematical considerations to determine survival and hazard rate. Similarly, as in the case of [5], the authors noticed that Al_2O_3 in natural esters that are tested proved to be effective against electrical, physical, and thermal stress.

Different liquid dielectrics (synthetic ester, natural ester, and mineral oil) were considered in [7] in terms of energy distribution of optical radiation emitted by the surface discharges. The liquid's influence on the emitted radiation range, such as the clear recognition, may be observed between the discharges developed in a given liquid.

A similar range of research in [7] was performed in [8], but in relation to the electric arc in the air. In addition to the AC voltage of different frequencies, the authors also considered DC voltage stress. They found differences in the percentage share of optical radiation energy for the particular spectral ranges when the arc is generated at AC and DC voltage. The authors highlighted the advantages of the used measurement method that may be helpful in the design of some apparatus where the electric arc is an undesirable phenomenon.

The results of the studies on glass-reinforced epoxy (GRE) core rods used in AC composite insulators with silicone rubber housing are presented in [9]. The authors subjected the samples to a temperature of 50 °C for 6000 h and AC and DC voltage, respectively. The 3 point bending test, micro-hardness measurement, and microscopic analysis were used as the comparative testing methods for the two mentioned aging tests. The findings from the measurements were that the microstructure of the GRE material can withstand the tests at both AC and DC voltage without reduction in its mechanical parameters.

The development of solid materials for transformers is also visible on the market, especially in relation to materials that can be subjected to high temperatures. Two papers presented the considerations on aramid-based paper applied in transformer applications [10,11]. In [10], the authors compared the influence of moisture content on the thermal conductivity of Kraft paper and aramid paper impregnated with different dielectric liquids, namely mineral oil, synthetic ester, and natural ester. The higher increase in thermal conductivity caused by moisture was observed in the case of cellulose paper than in the case of aramid one. At the same time the samples impregnated with mineral oil indicated higher thermal conductivity at the same moisture level. On the basis of the obtained relationships, the authors of [10] elaborated the equations that may be applied for determining the temperature field of the transformers at the design and operation stage. In turn, the authors of [11] tested the cellulose paper enhanced with aramid in terms of the polarization and depolarization current analysis method (PDC Method). The samples were analyzed from the viewpoint of accelerated thermal degradation as well as weight-controlled dampening. On the basis of the performed tests, the authors proposed the regression functions for the activation energy and the dominant time constants dependent on the parameters of the experiment representing the degree of aging. The findings of the authors may be used in the diagnostics of cellulose–aramid insulation applied in power transformers using the PDC method.

The studies related to the transformer diagnostics continued in [12], where frequency response analysis (FRA) was considered as the method for the detection of mechanical faults or short-circuits in transformer windings. The transformer with deformations introduced into the winding was compared with a 10 MVA transformer working at industrial conditions. The clue of the paper was to perform the analysis for various window widths and for various extents of the deformation. The results show that the choice of the data window width influences the results of the analysis performed. In addition, the rules for element number selection differ for various numerical indices.

Finally, the partial discharge detection in a non-uniform field in mineral oil was analyzed in [13] using the registration of even harmonic components in the leakage current. It was found that the fifth harmonic is dominant when partial discharges develop independently of the setup configuration and independently of the material used as the high voltage electrode. In addition, harmonics are correlated with the intensity of partial discharges and level of non-uniformity.

As presented above, this special issue covered a wide area of research on insulating materials of different types together with different measurement methods applied to assess the condition of these materials in the laboratory as well as in service. As the guest editors of this Special Issue, we would like to thank all the researchers who made their contribution to this Special Issue, as well as the reviewers who were involved in the assessment process that wished the papers included will be widely read and cited.

Conflicts of Interest: The authors declare no conflict of interest.

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