

Engineering Dielectric Liquid Applications

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1. Introduction

Engineering liquid dielectric applications in electrical apparatus is a field of study that mostly revolves around condition monitoring, performance analysis, aging, diagnostic, and prognostic studies. Liquid dielectrics in the power engineering domain are used for filling and impregnation purposes in various important electrical apparatus. The potential functionalities of these liquids include: Providing electrical insulation, acting as a coolant, and serving as a diagnostic medium. Liquid dielectrics in electrical apparatus have a significant history and have made a remarkable journey in serving the electrical power industry. Their effective functioning over the years has ensured reliability and efficiency in the smooth operation of electrical grids and in ensuring safety for the equipment and personnel in operation.

Since the inception of liquid dielectrics, they have been subjected to rigorous research for ensuring the effectiveness in serving their functions to the industry. Over the last few decades, numerous liquids have been used in research, which only a few have survived in terms of serving the intended purpose successfully and consistently. Mineral insulating oils extracted from crude petroleum stock have been put in service for a long while. However, in recent years, mineral oils have been facing industrial and environmental critiques owing to the developments in the high voltage sector and environmental regulations.

Researchers are making extreme efforts in introducing an appropriate replicate for the existing oils, while several researchers are placing emphasis on modifying the existing ones while including nanotechnology and materials research. However, the contemporary scenario pertaining to the field of liquid dielectrics is in a transit phase in shifting the technology to meaningful and better directions, to meet industry's needs. Numerous research records are positive towards the usage of ester-based biodegradable fluids. Pertaining to all these issues, this Special Issue has been organized with the title "*Engineering Dielectric Liquid Applications*", while emphasizing on electrical apparatus.

This Special Issue was focused on theoretical and practical developments, with special emphasis on engineering problems, in using dielectric liquids in electrical equipment. The applications of new fluids and perspectives were also of particular interest. Listed below, among others, are some the topics of interests considered:

- The application and performance of dielectric liquids;
- Electro-hydrodynamic phenomena and related applications;
- Breakdown and pre-breakdown phenomena;
- Electrostatic charging tendency;
- Insulating liquids efficiency improvement by chemical admixtures;
- Nanofluids and synthetic/vegetable dielectric liquids;
- Measurement, monitoring and diagnostic techniques;
- Fundamental investigations and basic properties.

The topics of the Special Issue aimed at improving the knowledge on existing and new insulating oils in satisfying the requirements of the industry while meeting health and safety regulations. This Special Issue also aims to contribute towards gearing up the research in the application of ester dielectric fluids in oil-filled electrical apparatus.

2. An Outlook of the Special Issue

Engineering Liquid Dielectric Applications, a Special Issue from *Energies*, has been successfully organized with the support extended from the Editorial team of the Journal and the MDPI publishing team. The average processing time of the articles was noted to be 32.16 days; this is only possible because of the time allocated by the reviewers in reviewing the articles. We would like to thank all reviewers for their prompt response during reviewing and revising the manuscripts. This Special Issue has received a good response from researchers, with a remarkable geographical distribution of papers. From the 15 submissions, 10 were accepted. The accepted papers include research from different countries, including Canada (2), China (4), the Czech Republic (1), Germany (1), Poland (1), and Spain (1). Working with insulating oils in the laboratory requires a lot of patience and is exhaustive, particularly for aging studies. We would also like to thank all the researchers who made their contribution to this Special Issue.

At the outset, acceptance and rejection of manuscripts is attributable to several criteria, with major factors including the novelty of the work, state of the art of study, and impact of the article on the existing literature. Importantly, the level of innovation, presentation of the work in the manuscript, hypothesis, and interpretations of results are other factors which make an impression on the reviewers and which may determine the inclusion of an article. Manuscripts possessing the aforementioned features will always be treated as successful and accepted for publication, to be shared with the scientific community. The successful and accepted papers in this Special Issue include 9 research articles and 1 review article in the allied areas of engineering liquid dielectrics. The summary of the articles published in this issue is discussed in the subsequent sections of this editorial.

3. A Review of the Special Issue

Qin et al. [1] experimentally investigated the influence of bubbles on the breakdown voltages of transformer oil and oil-impregnated pressboard under 50 Hz alternating current and direct current (DC) voltages while considering cylinder-plan, sphere-plan electrodes, and cone-plan electrodes. It is reported that, under the influence of bubble, the breakdown voltage of the cylinder-plan electrode dropped the most and the breakdown voltage of the cone-plan electrode dropped the least. In DC, the decrease of the breakdown voltages of the cone-plan and sphere-plan electrodes influenced by the bubbles were much less than that in alternative current (AC). Additionally, for the oil-impregnated pressboard, the decrease of the breakdown voltage under DC voltage was more than that under AC voltage.

Articles [2,3] are in the lines of modifying the properties of insulating fluids using suitable nanoparticles. In [2], an attempt has been made by Mentlik et al. to improve the properties of the natural ester available in the Central European region that is a rapeseed (*Brassica napus seed*) oil. Authors tried to modify the properties of natural esters through percolation treatment and oxidation inhibition by a phenolic-type inhibitor and further using titanium dioxide (TiO₂) nanoparticles with a silica surface treatment. Authors reported and enumerated the dielectric properties, including breakdown voltage, the dissipation factor, and resistivity of natural ester by varying the concentration of the nanoparticles. Velasco et al. [3] focused on the comparison of positive streamers in three different systems: Mineral oil, nanofluids, and immersed dielectric solids in mineral oil. The challenges for the simulation of the streamer in liquid dielectrics with finite-element software have been also discussed. It is observed that the dielectric solid blocks the propagation of the streamer when it is submerged with a horizontal orientation, thus perpendicular to the applied electric field.

A mathematical model describing the kinetics of drying according to temperature, initial moisture, paper weight, final moisture, and extraction rate is proposed by Betie et al. [4], based on thermogravimetry analyses. The impact of moisture, weight, and temperature on the drying process has been investigated. Authors reported a mathematical model to describe the kinetics of drying according to temperature, initial moisture, paper weight, final moisture, and extraction rate. The amount of moisture removed at the end of the drying process has been also demonstrated by the authors, using the proposed model. In article [5], the effect of three different carboxylic acids on the aging of oil/paper insulation used in power transformers has been investigated experimentally. The observations have been correlated to the degree of polymerization. Authors concluded that present diagnostic techniques consisting of monitoring insulation oil conditions based on the total acid number (which is used as reclamation criterion) does not provide a true picture of the transformer condition, since this procedure cannot distinguish between different acid types and their influences.

Experimental investigations dedicated towards the performance of natural esters have been presented in [6,7]. Haegele et al. [6] reported the degree of inhomogeneity differences in breakdown voltage between natural ester and mineral oils while using lightning impulses at different electrode arrangements representing different fields in homogeneity factors and different gap distances. Authors also envisaged different electrode and conductor arrangements reported in the literature for oil breakdown voltage studies. Wang et al. [7] discussed the mechanisms characterizing fast and slow streamers in vegetable oil and mineral oil, based on their calculations. The electronic properties of typical molecules were calculated using the quantum chemistry method (B3LYP/6-31G*), based on the density function theory. It was reported that the insulation characteristics of triolein and tristearin are more likely to be degraded under an external electric field than those of 1-methylnaphthalene and eicosane.

Rozga et al. [8] presented the results of the studies on negative streamer propagation in a point-to-sphere electrode system with a pressboard barrier placed between them. Experimental investigations have been carried out on two synthetic esters and two natural esters in comparison to mineral oils. Based on the study, it was reported that the intensity of the discharge processes, comparing the same voltage levels, was mostly higher when streamers developed in ester liquids. Zhang et al. [9] studied the performance of new alternative insulating oil/paper systems based on ester/Nomex, respectively, for high temperature applications, based on a typical loading curve on the China Southern Power Grid. Authors evaluated the physiochemical and mechanical properties along with the thermal index of the oil paper insulation system and reported that the considered new oil/paper insulation system is a promising one for high thermal applications compared to mineral oil/kraft paper insulation systems.

As discussed earlier, this Special Issue also reports on a comprehensive survey by Wang et al. [10], considering 132 citations on existing and new insulating oils for transformer insulation technology. In this survey, authors emphasized and highlighted the basis properties, variation in electrical properties with aging, nanomodified insulating oils, and recent studies on the performance of mineral oil (molecular and atomic levels). Finally, future research hotspots and notable research topics are also discussed for the benefit of researchers.

4. Closing Remarks

Insulating materials are still the Achilles' heel of power equipment. When this type of equipment fails, the cause can generally be traced to insulation degradation/aging. A wide variety of types of insulation is available, spanning all three forms of matter (solid, liquid, and gas), with sometimes a single form involved, but often a combination of forms, such as the solid/liquid or solid/gas forms. Liquid dielectrics are used in a wide range of power equipment, including transformers, reactors, capacitors, etc. The contributions in this Special Issue discuss a wide range of liquid dielectric applications relevant to engineering. Even though very interesting results have been reported, there are still many challenges to be solved in order to meet industrial requirements. Fundamental

studies are still needed to improve our basic understanding of the mechanisms involved in insulation system degradation and biodegradable fluid applications in various power components connected to power grids.

In the actual grid components, the insulation system was mostly designed to operate at normal power frequency voltages, with occasional lightning and/or switching transients. However, in today's grids, with the large penetration of renewable energy sources/plug-in vehicles, the reliability of insulation systems has to be improved. Nanotechnology is poised to play an important role in the insulating fluid industry by enhancing the physicochemical properties.

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