Aged transformer oil analysis through laser induced breakdown spectroscopy

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A novel approach in aged transformer oil analysis through laser induced breakdown spectroscopy

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Abstract

Periodic inspection of power transformers is important to prevent possible failures in power systems. One effective approach is transformer oil analysis. In recent years, the need for a fast, accurate and in situ method has been increased significantly. This research has employed laser-induced breakdown spectroscopy (LIBS) to analyze transformer oil and investigate its aging. For this purpose, changes in the intensity of molecular emissions (C₂, CN and OH) and their correlation with aging processes have been used. Spectral investigation showed that Cu lines had been added to the spectra of aged samples. Additionally, the principle component analysis (PCA) method was used to check and compare the overall spectra. Finally, the results of Gas Chromatography (GC) and Acid Number (AN) tests were given to confirm the age of the samples.

Keywords: Laser induced breakdown spectroscopy, transformer Oil, Aging, Principle component analysis and Gas chromatography
1- Introduction

The power transformer is one of the important equipment in power systems which the reliability of systems depends on the health of these. So, maintenance, periodic inspection and repair are the technically and economically essential [1]. Transformer insulation comprise cellulose paper and mineral oil. In addition to dielectric insulation, transformer oil is also plays an important role in cooling and arc extinguishing. Therefore, in order to ensure that the operation of the transformer at its nameplate rating, dielectric and coolant properties of the oil must be in normal condition [2, 3].

Transformer oil is available for sampling, which provides important information about transformer oil ageing, paper insulation health status, as well as the occurrence of mechanical stress, electrical faults and partial discharge inside the transformer [4]. Insulation aging and abnormal operating conditions of the transformer change the chemical, dielectric and physical properties of oil and cellulose paper in such a way that moisture, various gases, sludge deposits, acids, metal particles and other compounds will be increased in the oil. In this way, monitoring and checking the condition of oil can be a tool to detect faults and prevent transformer catastrophic failures [5].

The online protection system allows us to detect faults before the circuit breaker is suddenly shut off. This offers numerous benefits, such as preventing unexpected shutdowns, reducing transformer damage, and increasing the duty cycle, resulting in a longer lifespan and optimal utilization [6, 7]. Conventionally, Dissolved gas analysis (DGA) as a chemical method is usually used for this purpose[8, 9]. The use of lasers for transformer oil analysis has increased significantly in recent years. Various methods of laser analysis have been described, including Raman [10], fluorescence spectroscopy [11], FTIR
spectroscopy [12], Laser illumination planar imaging [13] and laser induced breakdown spectroscopy (LIBS) [14].

Recently, LIBS has become a dependable technique for elemental analysis. It has many advantages, including non-destructive, simultaneous multi-elemental analysis, rapid detection, no pre-treatment, portable and on-site analysis, making it an attractive option [15, 16]. It has been successfully employed in a variety of fields, including material science [17], chemistry [18], biology [19], geology [20], and the analysis of explosives and high-energy materials [21].

In the present work, LIBS technique were used to study transformer oil and its aging. For this purpose, we used transformer oil samples with natural aging during the transformer operation. Spectroscopy results on the samples gave us significant results. The changes in the intensity of some spectral peaks, especially the molecular radiations due to aging, were in good agreement with our predictions, chemical reactions, and the results of other colleagues. Also, in order to check and validate them more accurately, the statistical method is used and the results of gas chromatography (GC) and acid number (AN) analysis, which are standard methods in the field of oil analysis, are also given.