A Novel Graphical Method for Interpretating Dissolved Gases and Fault Diagnosis in Power Transformer Based on Dynamique Axes in Circular Form

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***Abstract*— Dissolved Gas Analysis (DGA) in oil is one of the most common and reliable techniques for diagnosing and early detection of incipient faults in oil-immersed transformers. However, traditional methods often encounter conflicts and challenges in accurately interpreting DGA results. Addressing this, a novel graphical method is proposed, represented by a circle with a movable axis at variable angles. This method is based on the convergence of samples that share the same characteristics around their centers and the spacing of these centers for samples that differ in characteristics from each other. Its purpose is to distinguish between different overlapping faults. Numerous potential solutions are derived to achieve this objective, the Gray Wolf Optimization (GWO) algorithm is used to determine the optimal angles that yield the best distribution of samples. Utilizing insights from previous DGA methods and field experiences, initial fault zones within the circle are estimated, and precise boundaries between fault zones are established based on practical DGA data collected from multiple sources. Evaluation using a range of fault cases demonstrates that the circle method exhibits superior diagnostic accuracy compared to existing methods, including the Mansour Pentagon, the Duval Pentagon, the Duval Triangle, the Gouda Triangle, the Three Ratios Technique, the Clustering Method, and Key Gases with Gas Ratios.**

Index Terms*— Dissolved Gas Analysis, oil-immersed transformers, Fault diagnosis, circular graphical form method , optimization.

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I. Introduction

Power transformers play an essential role in ensuring safe and reliable electrical power. Therefore, continuous maintenance of these transformers is crucial to ensure the smooth transfer of energy without interruptions, ultimately leading to consumer satisfaction [1].On the other hand, sudden faults and setbacks in power transformers, particularly those involving the active components, insulator damage, and pressure issues, can result in costly material losses and pose a significant threat to the entire system's integrity [2].Generally, the insulating component, comprising oil and paper, stands as one of the most critical elements in power transformers. Consistent monitoring of the condition of the oil and paper insulation contributes significantly to extending the lifespan of power transformers [3].When insulators deteriorate due to faults, the insulating oil undergoes decomposition and oxidation, resulting in the generation of various dissolved hydrocarbons. These hydrocarbon gases encompass hydrogen (H_2), methane (CH_4), acetylene (C_2H_2), ethylene (C_2H_4), ethane (C_2H_6), carbon monoxide (CO), and carbon dioxide (CO_2). All of these gases are emitted as a consequence of deterioration and dissolve within the oil, typically measured in parts per million (ppm) [4].Indeed, combustible gases with high individual or ratio gas generation rates serve as clear indicators of a fault within a power transformer and can help determine the fault level [5].Dissolved Gas Analysis (DGA) is a widely adopted method among power transformer maintenance professionals. DGA is a non-invasive monitoring technology that offers valuable insights into the condition of the insulation system and, more broadly, the internal components of the transformer [6].

DGA is presently one of the most commonly employed diagnostic tools used to monitor and detect early-stage faults in power transformers [7].To precisely diagnose the type of fault in power transformers, there are various methods for interpreting the results of dissolved gas analysis. These methods encompass ratio techniques and graphical techniques [8].DGA techniques have evolved over the years to enhance the safety and reliability of power transformers. Modern DGA methods have advanced significantly beyond the old, traditional techniques, reflecting ongoing efforts to improve transformer diagnostics and maintenance practices.

The Donberg method [9]**,** the Roger method [10], and the IEC method [11] are considered old traditional methods for DGA. Their main shortcomings often become evident when dealing with malfunctions that fall outside the specified codes, making interpretations unreliable. In an effort to overcome this challenge, the Duval method [12] was introduced. However, despite its simplicity and utility, it relies solely on three gases: CH_4,C_2H_2, and C_2H_4. This limitation can lead to inaccuracies