The Mechanism of Gassing in Power Transformers

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***Abstract*- Gassing of oil is defined scientifically as the chemical decomposition of certain hydrocarbons, under the impact of electrical and thermal stress. Indeed, the homolytic breakdown of vulnerable covalent bonds generates both small and large free radicals. The small ones become gases dissolved in the oil, while the large fractions generate insoluble colloidal suspensions. Currently, the electrical power industry believes that the gassing of oil is caused solely by hidden incipient electrical failures. Consequently, these are detected and diagnosed by periodic Dissolved Gas Analysis (DGA). This paper provides experimental evidence that the formation in service conditions of undetected oil-born decay products is a contributing factor to the gassing of oil.**

I. INTRODUCTION

The outstanding technical and economical importance of power transformers in the electrical transmission and distribution networks does not need to be discussed. Continuous awareness of the evolution of the conditions of the insulation system is of great value for the system operator as it allows optimising the lifecycle management of the machine as well as the scheduling of the maintenance operations.

Because of good dielectric and aging properties, coupled with wide availability and cost benefit, petroleum-based transformer oils are probably the most widely used electrical insulating liquids in the world today - and have been for the past century. It is known that in service conditions, the quality of mineral insulating oils gradually deteriorates under the impact of electrical, thermal and chemical stress. It is also recognized that the incipient electrical failures such as hot spots and partial discharges, resulted from the slow accumulation of oil-born decay products, are responsible for the gassing of oil. Gassing of oil is defined scientifically as the chemical decomposition of certain hydrocarbons, under the impact of electrical and thermal stress. Recent studies have shown that the gassing of oil has important side effects, since the breakdown of hydrocarbon chains generates not only soluble gases, as has been known for some time, but also invisible colloidal suspensions [1].

Gassing of oil was previously defined as the gas evolvement of insulating oils under the impact of electrical stress. New findings indicate that this definition is no longer adequate. According to a major insulating oil manufacturer, the oil evolves gases even under thermal stress at low temperature [2]. This newly discovered type of gas evolvement is called "stray gassing". Researchers for the electrical power industry have confirmed the existence of this phenomenon [3]. Concomitantly, ASTM International has developed and approved a laboratory technique that determines this characteristic analytically [4]. Currently, the cause of gassing is based upon the empirical interpretation of DGA as performed by professional organisations and commercial laboratories, in order to determine the real cause of gas evolvements, the mechanism of gassing requires a scientifically sustainable foundation. The result will be a reduced cost of maintenance procedures and enhanced service reliability.

II. THEORETICAL BACKGROUND

The build up of gaseous decay products in insulating oils during service results mainly from the breakdown of valence bonds in vulnerable hydrocarbon molecules. To understand the mechanism by which, this process occurs it is important to identify the energy source that triggers the decomposition of low stability hydrocarbon chains.

Excited molecules produced by the *primary process* of energy absorption can undergo a variety of *secondary processes*, both physical and chemical. Typical processes that affect the electrochemical stability of this blend of more than 3000 components are:

- the splitting of excited molecules into smaller fragments,
- transfer of energy to other molecules; or
- their return to the ground state by releasing absorbed energy.

A. Primary Physical Processes

Free electrons are the primary source of energy for the breakdown of vulnerable covalent bonds (approximately 4 eV ≈ 386 kJ mol^{-1}). Pioneering work by Forster [5] describes the mechanism by which high-voltage fields interact with insulating oils. His extensive research in this field reveals that electrons escape from the conduction band of the metal conductor and are emitted from its surface, especially during very short but frequent commutation voltage surges [6]. Lesser quantities of energy below this threshold simply will not do the job. The free electrons injected into the liquid insulation are accelerated by the electric field. The collision of a fast electron with a hydrocarbon molecule M may be either elastic or inelastic, leading to very different results:

(i) Elastic collision: