Enhancing the Maintenance of Transformer Oils to Diminish the Risk of Blackouts

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Rezumat: **Există părerea unanimă că în condiții de exploatare calitățile uleiurilor minerale izolante se deteriorează treptat ca urmare a solicitărilor electrice, termice și chimice. Se apreciază, de asemenea, că numai străpunferi electrice incipiente cauzate de intensificări locale ale câmpului electric sau descărcările parțiale ar fi responsabile de sporirea conținutului de gaze în masa de ulei. Totuși, în cazul deteriorării izolațiilor din hârtie, relația dintre cause și simptome nuj este foarte limpede înțeleasă. Articolul intenționează să arate că apariția în ulei a compușilor gazoși constituie rezultatul unor fenomene mai complexe. Compoziția chimică a amestecului de hidrocarburi și apariția produselor de descompunere sunt și ele factori ce contribuie la formarea gazelor dizolvate în ulei. Astfel, rezultatele unei analize a gazelor dizolvate oferă o interpretare mult mai corectă.**

Descriptori: **ulei de transformator, stabilitate electro-chimică, tendință de gazificare, produse de descompunere**

Key Words: transformer oil, electro-chemical stability, gassing tendency, decay products

Contributions

Our major contribution consists of the finding that there are several factors responsible for the gassing of oil. A basic cause is the chemical composition of hydrocarbon blend. Then the impact of heat, the oil-born soluble and insoluble decay products as well as the incipient electrical failures currently monitored by Dissolved Gas Analysis (DGA). The relationship between the analytical characteristics of oil assessed by more accurate ASTM tests methods, its gassing tendency determined by DGA and the very peculiar properties of oxygen molecule, provides convincing evidence that the dissolved oxygen must be completely eliminated.

For the quantitative removal of dissolved oxygen, innovative, economically viable and environmentally friendly maintenance procedures are suggested. Thus, not only the service reliability of aging transformers can be enhanced, but also their life expectancy extended and the cost of predictive maintenance diminished.

1. Fundamentals

There is a general agreement 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 incipient electrical failures such as hot spots a partial discharges associated with the gassing of oil are the result of the slow accumulation of oil-born decay products. Nevertheless, the relationship between the cause and the symptoms of paper insulation deterioration is not clearly understood.

Not long ago, a relatively new 200 MVA autotransformer of 220 kV located in a European country was de-energized by the Bucholz relay. Suddenly, the power grid collapsed leaving a heavily industrialized area without electricity for several hours. A team of highly qualified specialists investigated the cause of this failure but nothing wrong was found. Finally, the unit was energized again with excellent results. Sadly, the cause of the instant gas evolvement that sent a shock wave to the gas relay remained an unsolved mystery. The investigators agreed that the decomposition of oil was triggered by a voltage surge. However, no consensus could be reached regarding the mechanism by which the electrical stress could be converted into the energy necessary to split strong chemical bonds between the atoms of hydrocarbon molecules and generate a large amount of fault gases.

In fact, the breakdown of certain unstable hydrocarbon molecules is dependent on two major factors: the chemical composition of the blend and the incipient electrical failures. A transformer manufacturer recommends the following actions based on the observed concentration of fault gases [1]:

a) 0 to 500 ppm: Represents normal aging. Analyze again in six months.
b) 501 to 1 200 ppm: Indicates decomposition may be in excess of normal aging. Analyze again in six months.
c) 1 201 to 2 500 ppm: Indicates more than normal decomposition. Analyze again in one month.
d) 2 500 ppm to more: Make weekly analysis to determine rate of generation. After establishment of rate of generation, contact manufacturer concerning future operation.

Such advice does not recognize the need for maintenance planners to know why the oil is gassing and what is to be done to avoid potential failures. IEEE [2] underscores the lack of success of the Dissolved Gas Analysis (DGA) to detect incipient electrical failures and „diagnose" their cause by analyzing the fault gases. Many companies around the world are still keeping their units in service with combustible gases levels well over the alarm levels on the standards.

This article describes laboratory test methods capable of monitoring the deterioration of oil step by step, thus establishing the impact of the purity of the liquid insulation on the performance of solid insulation and making the cost of oil maintenance economically justifiable.

2. Theoretical Background

Chemically, mineral oil consists of a complex mixture of basic hydrocarbon liquids (40 to 60% paraffins, 30 to 50% naphtenics, 5 to 20% aromatics and 1% olefins [3].

Decay products cannot be formed without breaking the hydrocarbon chains. Table 1 shows the energies needed to rupture the bonds found in hydrocarbon molecules [4].

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