http : //www.cigre.org

2018 Paris Session

SC D1 PS3 «Testing, monitoring and diagnostics» - Advanced condition assessment

Evaluation of the paper insulation condition of power transformers based on the content of methanol dissolved in transformer oil

L.A. Darian[*]([a]), R.M. Obraztsov([a]), A.V. Maksimchenko([a]), L.K. Le([b]),
[a] JSC «Technical Inspection UES»
Russia
leonid.darian@gmail.com
[b] Electric Power University
Socialist Republic of Vietnam

Power transformers are one of the most important types of equipment of power plants and substations. The lifetime of a power transformer is determined by the condition of its paper insulation, which is evaluated by means of polymerization degree (DP). In its turn, DP is assessed using aging markers - decomposition products of paper insulation dissolved in transformer oil. The aging markers are divided into three generations.

The first generation markers include water, carbon monoxide and carbon dioxide, the second ones – furanic compounds. The third generation markers comprised of methyl alcohol (methanol). It is known that the rate of formation of all aging markers is affected by a variety of factors, for example, oil temperature, transformer design, paper type and its moisture content, oxygen concentration in oil. Estimation of the paper insulation aging degree by the amount of decomposition products of paper insulation is arranged by means of experimental dependences establishing the relationship between the paper insulation DP and the amount of decomposition products of paper insulation formed and dissolved in the transformer oil. Unfortunately, it is not possible to establish a unique relationship between the amount of first and second aging markers and the degree of aging (depolymerization) of paper insulation for equipment in operation. The preceding issue is faced as an increase of moisture content, carbon monoxide and carbon dioxide in transformer oil can occur because of ambient air ingress. As for second generation markers, furan derivatives are likely to decompose in transformers equipped with adsorption and thermosiphon filters, ending up with its underestimated value. Thus, the first and second generation aging markers cannot provide a reliable estimation of the paper insulation aging degree under operation conditions.

In recent years, there has been a significant increase in interest in the decomposition products of paper insulation – methanol. This chemical compound meets the basic requirements applied to aging markers of paper insulation. In addition, methanol is free from the drawbacks of first and second generations aging marker.

The literature review, chiefly focusing on methanol generation under high-temperature conditions, has shown the topicality of research in two main areas:

- enhancement of the test method and expansion of the nomenclature of materials involved, in particular, for paper insulation and transformer oil produced in Russia;
- data collection on the methanol content in transformer equipment of various designs and age, as well as operating conditions.

In the experiment, carried out by the authors, the cable paper "K-120" and transformer oil "GK" grade, manufactured in Russia, were taken as test peace.

The experiments were carried out for three groups of samples of paper insulation with different initial moisture content: 2%, 1%, and less than 0.5%. Prepared samples of cable paper were placed in test cells of a special hermetic design, ensuring compensation of oil temperature expansion under paper aging conditions and temperatures up to 130 °C. The

paper-oil ratio of 1/18 (by weight) was chosen, as it reflects an average indicator for distribution power transformers operating in the Russian Federation.

An important requirement for conducting accelerated aging of cable paper samples is to ensure that the same temperature is maintained in all the cells (more than 50) during the experiment. To meet this requirement, the test cells were placed in a specially designed circulation bath with a liquid heat carrier. The circulation bath made it possible to maintain a temperature gradient in the volume of the heat transfer fluid of not more than 0.1 °C, which provided identical aging conditions for the test paper insulation samples in all test cells during the experiment.

Analysis of transformer oil for methanol was performed on a specially configured chromatographic complex of Russian origin. The chromatographic complex allows to reliably register the concentration of methanol in the transformer oil at the level of 10 ppb.

A curve of DP of paper insulation "K-120" versus methanol concentration in transformer oil "GK" was obtained as the result. It was compared to the results of similar researches conducted in laboratories of different countries. The comparative analysis showed that the oil grade and type of paper insulation do not affect type of the dependence. However, the values of methanol concentrations at the same paper insulation DP differ for different manufacturers. This fact was explained.

Based on obtained dependencies, a method for interpreting test results in order to assess the insulation paper conditions was proposed. The method in question was tested on transformers in operation. For this purpose, testing of 94 distribution transformers of 35-110 kV, operated in the Russian Federation, was carried out. An abnormally high concentration, in comparison to this-age average, of methanol was registered in oil samples of two transformers. One of these two transformers was disassembled. The DP of its paper insulation proved to be close to critical, so was indicated by the high methanol concentration. This result confirms the practical significance of the proposed method for assessing the paper insulation condition of power transformers based on the content of methanol – the third generation aging marker.

While approbating the method, the authors came up with another important finding: it is advisable to use the dependency of methanol concentration per oil unit volume versus insulation paper DP instead of methanol concentration versus insulation paper DP while testing power transformers in operation. This approach allows one to take into account the design and manufacturing technological features of power transformers.

The currently ongoing research is aimed to method reliability enhancement. For this purpose, oil methanol content of operating power transformers of various designs are collected and analyzed.