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ScienceDirect

Procedia Engineering 202 (2017) 13–19

Procedia Engineering

www.elsevier.com/locate/procedia

The Research of Methanol Generation in Aging Paper Insulation

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Abstract

The paper presents the results of studies of the generation of methanol in the accelerated aging of paper insulation in transformer oil under the influence of an elevated temperature. All investigated materials (cable paper, transformer oil) are of Russian origin. A description is given for the used models of paper insulation samples, specially designed test cells and a circulating bath. The results of a comparison of studies conducted by authors and other researchers from countries are analyzed.

Peer-review under responsibility of the organizing committee of ICTRAM 2017.

Keywords: Cellulose degradation; degree of polymerization; paper insulation; methanol

1. Introduction

Power transformers are one of the key components of substation equipment of distribution network. Service lifetime of a power transformer is determined in accordance with condition of paper insulation. Methanol is considered to be one of degradation product of cellulose paper [1-3] therefore the research of methanol generation in power transformers being in service at substations of distribution network is of special interest.

The degree of polymerization (DP) is a quantitative indicator of the state of paper insulation [4]. DP is determined by the viscosity of its solution in a solvent in accordance with IEC 60450. However, this method of DP evaluation has a significant drawback for the power transformers being currently in service to determine the DP by this method, it is required to select a sample of paper insulation from within the transformer, which leads to the need for taking it out of service and opening the transformer tank. In addition, to obtain reliable results, it is recommended to take the sample of paper insulation from hotspot (for example, in proximity of the upper part of the low voltage winding). After that, it is required to restore the insulation of the winding, which is quite difficult and requires high qualification of men.

As by now, indirect way of assessing the state of paper insulation – by means of evaluating the content of transformer oil first and second generation indicators or aging markers have not found widespread application [3]. The term "aging marker" refers to solid, liquid or gaseous decomposition products of paper insulation in transformer oil, by a content of which the DP can be estimated. Over the past decade, researchers from several laboratories have been studying a new aging marker for paper insulation – methanol, appearing as the third generation aging marker. The results of the analysis of publications, carried out by the authors, confirm that methanol meets the basic requirements of aging markers [3]:

- solubility in transformer oil;
- adsorption properties, allowing to measure its residual amount after the replacement or regeneration of the oil;
- chemical stability is sufficient for practical purposes.

1877-7058
Peer-review under responsibility of the organizing committee of ICTRAM 2017.
10.1016/j.proeng.2017.09.690

The properties of methanol, as aging marker, make it attractive for assessing the state of paper insulation operated at substations of distribution networks.

2. World experience of research methanol generation during thermal aging of paper insulation

Research of methanol generation in transformer oil under the influence of temperature have been conducted for more than 10 years. It is worth noting that the physical models used by different researchers for both samples of paper insulation and test cells differ significantly from each other. This circumstance may affect the final results, namely, the dependence of DP of paper insulation on the amount of methanol dissolved in the oil.

In [5], a part of copper conductor, wrapped in four-layer kraft paper, was proposed as a physical model. The mass of paper insulation was 1.7 g. Two groups of paper insulation samples, differing in their initial moisture content – less than 0.5% and 1% respectively – were tested. Each sample of paper insulation was placed in a 200 ml glass ampoule (test cell) filled with 100 ml of unused uninhibited naphthenic insulating mineral oil. The ratio of the mass of the oil to the mass of the paper insulation was approximately 50/1. Before the test cell was sealed, its free space was filled with argon. Aging of the paper insulation samples, prepared in this way, was carried out for a period of several months in three temperature regimes: 98 °C, 110 °C and 122 °C. It should be noted that samples of paper insulation with a moisture content of less than 0.5% were subjected to tests at 110 °C. Unfortunately, this publication does not contain information on the spread of temperature values between test cells in a group of a common temperature regime. The number of samples, involved in each experiment, is also not specified. After a certain time, the glass containers were removed from the furnaces and the paper insulation DPs were determined in accordance with IEC 60450. The transformer oil was analyzed for the content of furfural and methanol. Measurement of the methanol concentration was carried out by means of a Gas Chromatography coupled with Mass Spectrometer. Measurement of the furfural concentration was carried out by high-performance liquid chromatography in accordance with IEC 61198.

As the result of above mentioned tests, the dependence of methanol and furfural concentrations in the transformer oil on the DP of the paper insulation was obtained. However, it should be noted, that test design had one significant drawback: the gas space, formed in the upper part of the test cell, is expected to be filling by methanol over the duration of insulation aging process, with the quantities determined by the distribution coefficient between transformer oil and argon. Opening such a vessel results in a leakage of methanol, having a negative impact toward methanol-DP curve.

In 2015, the results of accelerated aging of paper insulation in transformer oil at the temperature of 120 °C were presented at Colloquium of A2 CIGRE Research Committee in China [6]. As the test samples, Gemini X inhibited oil was used. The paper insulation grade was not indicated. The ratio of the oil mass to the mass of the paper insulation was 20/1. Unfortunately, no information was presented on the methods and instruments, used for determination of the content of methanol in transformer oil and paper insulation. The design of the test cells was not depicted as well.

Thus, the preceding literature sources do not contain the information, sufficient for unambiguously interpretation and comparison of the results obtained. It should be noted that in order to identify the relationship between methanol generation and DP of paper insulation, it is