energies

MDPI

Article

Regeneration of Transformer Insulating Fluids Using Membrane Separation Technology

Leila Safiddine [1], Hadj-Ziane Zafour [1], Ungarala Mohan Rao [2] and Issouf Fofana [2,*]

[1] Université Saad Dahlab Blida, Laboratoire de Génie Chimique, Route de Soumaa, Blida BP 270-09000, Algeria; l.oumert@hotmail.com (L.S.); amelzafour@yahoo.fr (H.-Z.Z.)

[2] Research Chair on the Aging of Power Network Infrastructure (ViAHT), University of Quebec in Chicoutimi, Chicoutimi, QC G7H 2B1, Canada; mohan.ungarala1@uqac.ca

* Correspondence: Issouf_Fofana@uqac.ca; Tel.: +418-545-5011 (ext. 2514)

Received: 30 November 2018; Accepted: 17 January 2019; Published: 24 January 2019

Abstract: Oxidation of oil/paper insulation initiates premature aging and introduces carboxylic acids with eventual increase in oil acidity, which hampers the properties of the oil. In this paper, a membrane separation technology-based purification process for aged insulation oil has been evaluated and reported. The intent of the present study is to eliminate carboxylic acids, dissolved decay contents and other colloidal contamination present in aged oil and enhance the useful life of oil. The potential of the membrane treatment process has been demonstrated using Ultraviolet Visible Infrared Spectroscopy and Fourier Transform Infrared Spectroscopy diagnostic measurements for oil and membrane. Additionally, membrane retention properties like membrane flux, retention coefficient, sorption time and membrane mass have been analyzed to understand the treatment process. To further evaluate the performance of the membrane and effectiveness of the treatment process, acidity, dielectric dissipation factor, relative permittivity, and resistivity measurements of the oil before and after filtration have been also reported. The proposed membrane purification method has been tested for Algerian utility in-service oil samples. It is inferred that, membrane filtration method is a simple and effective method for treatment of aged oils and aids in extending the remnant life of the oil. The procedure is economically attractive because of increasing prices for transformer liquids, cost effective and environmentally sounds.

Keywords: transformers; insulation; regeneration; membrane separation

1. Introduction

The function of mineral insulating oil in power transformers is to provide insulation and cooling [1]. Insulation oil in transformers is used in coordination with insulation paper to form an insulation system. The insulation system in oil filled transformers is subjected to variable electric, thermal and chemical constraints that are responsible for its deterioration over time [2–4]. The presence of oxygen and humidity in the insulation system are evident due to operation of breather configurations and the degradation of the cellulose fibers in insulation papers. Oxygen and humidity promote early degradation of the transformer oil/paper insulation that leads to an increase in the acidity of the oil and a decrease in the dielectric resistance of the paper. The by-products of the oxidation and hydrolysis may be soluble in oil or settle at the bottom of the tank, thus contributing to oil sedimentation. The soluble by-products are diagnosed by (UV/Vis) spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), total acid number (TAN), dissipation factor (Tan δ), and interfacial tension (IFT) [5]. Similarly, insoluble by-products are quantified by the turbidity, particle counter, and color number [6].

Oxidation and hydrolysis of mineral oil produce acids with different molecular weights. Acids with high molecular weight will have lower affinity to cellulose than those with low molecular