C.8.3.1.

Microspectral analysis in UV-vis range as a tool for power cable insulation diagnosis

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Abstract: The aim of this work is to demonstrate the possibilities of microspectrophotometry in diagnostics of cable insulation ageing and partly – for technological microdefects recognition. The following processes are considered: thermal ageing of cross-linked polyethylene, sweatening out of antioxidant, treeing. Thermal ageing is also analysed for paper insulation as well as the effect of discharges. Phenomenological model for the material degradation, describing the evolution of spectra in terms of partial differential equation is presented. It is shown that optical parameters of dielectrics correlate well with their electrical and mechanical properties. Microspectral methods are able to compete successfully with traditional procedures.

Keywords: microspectral analysis, thermal ageing, water treeing, defects, impregnated paper insulation

Résumé: Ce travail a pour but de représenter les possibilités de la microspectrophotométrie pour diagnostiquer le vieillissement de l'isolation et partiellement discerner des défauts technologiques. On examine des procédés suivants : le vieillissement thermique du polyéthylène réticulé, l'exsudation de l antioxydant, le développement des arborescences d'eau. On analyse aussi le vieillissement thermique de l'isolation au papier imprégné des câbles, les effets des décharges pour elle. On propose un modèle mathématique phénoménologique pour le vieillissement des différents diélectriques qui décrit des variations du spectre en fonction du temps au moyen d'équation différentielle aux dérivées partielles. On a démontré que les caractéristiques optiques des matériaux se corrèlent bien avec les caractéristiques mécaniques et électriques. Les méthodes microspectrales peuvent avec succès faire concurrence aux méthodes traditionnelles.

Mots clés: analyse microspectral, vieillissement thérmique, arborescences d'eau, défauts, isolation au papier imprégné.

1. Introduction

Microspectrophotometry and microspectrofluorometry in ultraviolet (UV) and visible (VIS) range cover absorption, fluorescence and diffuse reflectance studies. This technique is relatively simple (in principle, but not in details) and inexpensive; our experience shows that UV/VIS spectra are highly sensitive to changes which take place in organic dielectrics due to ageing and degradation. However only a few publications dealing with the diagnostics of cable insulation by these methods are available – [1, 2]. We would like to contribute to the extension of this analysis applications for XLPE and impregnated paper insulation of medium and high voltage cables.

All measurements have been carried out by means of MSFU microspectrophotometer, combined with LUMAM fluorescence microscope (both manufactured by LOMO, St-Petersburg, Russia).

2. Thermal ageing of cross-linked polyethylene

This process is accompanied by an increase and a shift of absorbance and fluorescence to longer wavelengths as a result of polyenes accumulation with a clear tendency to stabilization of optical properties due to polychromatic kinetics – fig. 1. It is worth being noted that a small red shift of XLPE spectra corresponds to small changes in dielectric strength E_{br} (initial E_{br} = 141.4 MV/m, for cable aged during 45000 hours at 90°C E_{br} = 126.8 MV/m). Power factor (tanδ) increases to a somewhat higher degree, from 0.000289 to 0.000409 and this is more in line with larger variations in spectra dispersion and intensity (tanδ and E_{br} were measured on 0.2 mm thick ribbons cut from virgin and aged insulation).

Application of scanning stage technique provides observation of more localized phenomena which take place near semiconducting screens. For instance, fig. 2 exhibits two distributions of fluorescence near the outer semicon: one – after storage at room temperature, and the other – after relatively short-term exposure to 90°C. Fluorescence in this case is stipulated by the presence of an antioxidant: measurements clearly demonstrate sweatening out of the stabilizer and potentially poor resistance of the particular XLPE formulation against thermal ageing. A similar phe-