C6.9

An analysis of the interfacial region of HV cables using electrostatic force microscopy

BETTERIDGE S., BICC Cables Ltd, Wrexham, United Kingdom
LEWIS T.J., LLEWELLYN J.P., SEECS, University of Wales, Bangor, United Kingdom
HAMPTON R.N., BICC Cables Ltd., Erith, Kent, United Kingdom

Résumé

La technique EFM (microscopie des forces électriques a été appliquée pour étudier la microstructure des matériaux employés dans la fabrication des câbles. Cette technique, qui est dérivée de l'AFM (microscopie des forces atomiques), mesure les forces électriques à proximité des charges microscopiques à la surface. La technique a été employée pour enregistrer des images nettes de l'interface électrique dans les câbles HT. Ces images montrent des particularités conductrices pénétrant 2µm dans l'isolant. Les images EFM des différents types de câble (XLPE et EPR) montrent des degrés différents de régularité de l'interface. La technique EFM a également été employée pour mesurer la grosseur moyenne des particules de carbone dans l'écran sur âme.

Abstract

A novel application of Electric Force Microscopy (EFM) has been used to study the microstructure of cable materials. This technique, which is an adaptation of the Atomic Force Microscope (AFM), measures the electrical forces in the neighbourhood of microscopic surface charges. The technique was used to record clear images of the electrical interface in HV cables. These images show conducting features extending 2 µm into the insulation. EFM images of different cable constructions (XLPE and EPR) show different degrees of interface smoothness. A measurement of the average carbon particle size in the conductor screen was also made using the EFM technique

Introduction

The interface between the conductor screen and the insulation of a HV cable is considered to be a major site for the generation of electrical and water trees [1,2]. One reason for the location of trees in this region is due to the enhancement of electric fields at protrusions along the interface. The size and frequency of these protrusions along the cable have been reduced over the last thirty years through improvements to the extrusion process and by using 'supersmooth' semiconducting screen.

At low magnifications the quality of the interface can be investigated using optical microscopic techniques [3]. For greater magnification, transmission electron microscopy (TEM) [4] or scanning electron microscopy (SEM) can be used [5]. However it is sometimes difficult to distinguish the interface clearly, because both the insulation and conductor screen have been designed to have similar properties. In addition, the techniques required in the preparation of surfaces for TEM and SEM, e.g. etching, may modify the interface. It is therefore difficult to make a quantitative analysis of the roughness of the conductor screen-insulation interface on a microscopic scale using these techniques.

In this paper a new technique, based upon the Atomic Force Microscope (AFM), has been used to study the interfacial regions of HV cables. The Electric Force Microscope (EFM) measures the electrical interactions between the microscopic cantilever tip of the instrument and the surface under investigation. Stern et al [6] showed that the EFM could be used to measure microscopic areas of charge deposited on a polymeric surface. It can also be used to measure the potential of conductive surfaces via induced charge on the tip [7]. These methods can be applied to HV cables to highlight the interface between the conductor screen and the insulation, because of the different conductivities of these two surfaces. Therefore, since regions of different conductivity can be clearly distinguished in EFM images, it is possible to make an accurate measurement of the size of protrusions along the interface of HV cables.

In this paper the results of both AFM and EFM measurements on two XLPE insulated and two EPR insulated cables with different insulation and screen formulations are presented. Microscopic protrusions at the interface have been identified and a quantitative estimate of the interfacial roughness for all four cables has been made.

High-resolution images of the conductor screen surface, away from the interface were also recorded using both AFM and EFM techniques. From these images the structure and distribution of carbon within