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New interpretation of long-term test results of MV cables : Material ageing or internal defect structure development

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Résumé

Al'aide des méthodes de caractérisation on a recherché des cables à moyenne tension à XLPE qui ont été vieillis d'une manière électrique pendant deux années. Les câbles à moyenne tension avec des contraintes résiduelles faibles entre $7U_0$ et $14U_0$ étaient au centre d'intérêt. Les recherches ont montré que la formation des défauts dans l'interface entre l'XLPE et l'interface de la couche semiconductrice intérieure diminue énormément les contraintes résiduelles des câbles. Les défauts, appelés arbres d'eau, se sont formés déjà après trois mois de vieillissement électrique à l'interface intérieure. La formation et la croissance des arbres d'eau dans les câbles à moyenne tension sans protrusions à l'interface ont été recherchés au moyen de microscopie optique, électronique à transmission et par balayage. Les arbres d'eau dont les points de départ se trouvent à l'intérieur de l'interface de la couche semiconductrice, consistent surtout des polymères dégradés et peuvent détruire le XLPE quand ils atteignent l'interface intérieure.

Abstract

XLPE medium voltage cables aged in the long-term test for about 2 years were investigated by different structural characterization methods. The main focus was aimed at medium voltage cables with a low residual breakdown strength between $7U_0$ and $14U_0$. The formation of defects in the interface between XLPE insulation and the inner semiconductive shield reduced the residual breakdown strength of the cable system remarkable already after 3 month. This formation and growing of vented trees in MV cable without protrusions in the interface was investigated by light microscopy, scanning and transmission electron microscopy (SEM, TEM) and FTIR microscopy. The starting points of the trees were found inside the semiconductive layer. The defects are able to attack the XLPE insulation, if they reach the interface between insulation and semiconductive layer.

Introduction

Defects in medium voltage (MV) power cables formed by thermal, mechanical and electrical stress during a long ageing time are able to cause a failure of the cable system. For 20kV cables more than 300 results of 2 year tests by different cable companies are available in Germany.

Two different processes were discussed to explain the decrease of the residual breakdown strength of MV cables during the electrical ageing process:

1. a general ageing of all material applied in the cable system (oxidation of polymeric materials, migration and diffusion of low molecular components which are formed during the production, ageing or curing of cable systems)
2. formation of local defects, for examples water-trees or electrical trees, which caused the early breakdown of the cable system.

In order to achieve a better understanding of the well-known ageing figure, in this study potential XLPE material changes and the correlation with the breakdown strength were analysed in MV cable systems. The residual breakdown strength between $7U_0$ and $14U_0$ were found. MV cables with a strong decrease of breakdown strength already after 3 month were chosen. These selected cables were evaluated in the unaged and aged state concerning electrical properties, changes in crystalline structure, morphology and chemical structure in dependence of the electrical ageing time.

Materials and methods

The investigated cable samples are representative for the real material - respectively insulation systems status after cable manufacturing. The cable systems consist of XLPE- homopolymer dry-crosslinked with peroxide as insulation material, EEA-copolymer filled with acetylene carbon black (35 – 40%) crosslinked with peroxide as inner semiconductive layer, and stranded aluminium wire as conductor. The MV cable systems were aged