Close and Return

B.8.2. Caractéristiques de câbles MT vieillis en réseau

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B.8.2. Characteristics of field-aged medium-voltage cables

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Résumé

Cet article présente des résultats sur la caractérisation de plusieurs cables de distribution vieillis et claqués en service. La caractérisation comprend essentiellement des mesures du claquage c.a. (ACBD) d'échantillons de câble sous trois conditions: tel que reçu, sec and immergés dans de l'eau à 80°C pendant plus de 10000 heures. L'analyse des arborescences d'eau et des bris, ainsi que des mesures de teneur en eau de l'isolant furent également effectuées pour juger de leur influence sur la rigidité diélectrique. Les résultats indiquent que l'isolation de ces câbles peut contenir plusieurs milliers de ppm d'eau, laquelle quantité affecte significativement leur rigidité diélectrique résiduelle. Lorsque l'isolant est sec, le champ disruptif atteint approximativement 15 kV/mm, mais chute de moitié quand la teneur en eau augmente, cette décroissance s'explique non seulement par la présence de l'eau mais aussi par la régénération des arborescences d'eau qu'elle provoque. Plusieurs conversions d'arbres noeud-papillon et éventail en arbres électriques ont pu être observées.

Abstract

This paper presents results of a characterization of field-aged distribution cables which had failed in service. The characterization comprised essentially AC breakdown (ACBD) measurements of cable samples in three conditions: as received, dry and immersed in water at 80°C for more than 10000 h. Water tree and failure site analysis, and measurement of the water content of the insulation were also performed in order to assess their influence on the ACBD strength. The results indicate that the insulation of these cables can contain several thousands of ppm of water, which significantly affects their residual dielectric strength. When the insulation is dry, the ACBD strength reaches roughly 15 kV/mm but drops to half that value with an increase in the water content this decrease is explained not only by the presence of water but also by the regenerated water trees. Several conversions of bow-tie and vented trees into electrical trees were observed.

INTRODUCTION

Medium-voltage crosslinked polyethylene (XLPE) cables are constantly exposed to water, either during manufacturing, installation and operation. Most of the cables installed in the world were made using water steam-curing, an old-fashioned process which contributes to the formation of microcavities or water reservoirs in the insulation [1]. During manufacturing, cables are cooled also with water. It is only recently that cables began to be fitted with caps at the ends to prevent water coming in via the conductor strands. Finally, water will always be present in the cable environment during operation.

It is well known that the presence of water together with an electrical field leads to the formation and growth of so-called water trees in XLPE insulation [2,3]. Under certain service conditions (lightning, switching, interruption) these water trees can convert into electrical trees and, ultimately, lead to the breakdown of the cable insulation [4,5]. Thus, water can be considered a major aging factor of XLPE cables.

This paper presents the results on the characterization of seven field-aged distribution cables which have failed in service. It comprises water content of the insulation, residual dielectric strength, water tree and failure analysis. Since, in the field, these cables may have been exposed, alone or one to the other, to different environments, dry or in water, and since the storage conditions and the time elapsed between their withdrawal and testing were not always known, it was decided to test them in three conditions: as received, after drying and after immersion in water. This approach allowed us to also investigate the influence of water on the electric performance of field-aged cables.

EXPERIMENTAL

The cable characteristics used in this work are given in Table 1. These cables were removed from service after 6 to 17 years, either because they had failed in service or after a DC test, or simply to change a circuit. Most had steam-cured XLPE insulation and only one had high-molecular-weight polyethylene (HMWPE) insulation.

The residual AC dielectric strength was measured in conformity with the AEIC CS5-87 specification on six samples for each cable and condition. Essentially, the voltage was increased in 5-min steps, the first at 3,94 kV/mm and subsequent ones of 1,57 kV/mm, until breakdown. The active length of each cable sample was 5,5 m. According to the voltage level needed to break down the cable samples, SF_6 or deionized water terminations were used with different high-voltage sources. It should be pointed out that these two HV sources had different breakdown current limitations. As shown on Table 2, five cables were tested as received from the field, five after drying in a laboratory environment for a period ranging from 12 to 60 months and all after immersion in tap water at 80°C for up to 10000 h, except RI1 and RI2 which were immersed in tap water at 22°C for 17500 h. Tap water was also forced into the conductor strands and flushed occasionally to prevent gas pocket formation due to corrosion.

Since the hot-water immersion treament could also lead to impurity diffusion originating from the semiconductor shields in the insulation, impurity analysis was also performed. This was done by Neutron Activation Analysis (NAA) for seven elements: sodium (Na), potassium (K), calcium (Ca), chlorine (Cl), aluminum (Al), copper (Cu) and sulphur (S). Samples were taken from five insulation ribbons [6] roughly 10 m apart along two cables before and after the treatment, and five measurements were made per ribbon.