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Water penetration in the insulation of medium voltage cables

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Résumé
Cet article présente des résultats sur la teneur en eau de l'isolant de différents types de câbles extrudés moyenne tension soumis à des conditions simulées de service. Le but est d'évaluer la quantité d'eau qui peut pénétrer dans l'isolant lorsque les câbles sont cyclés thermiquement. Les câbles sont isolés au XLPE ou TRXLPE, avec ou sans gaine, réticulés à la vapeur d'eau ou à sec. Les câbles furent conditionnés dans un bassin d'eau à une température maximale de l'âme mesurée à l'extérieur de 90°C, sous une tension appliquée de $1xU_o$ et sans eau dans l'âme. L'influence de la gaine, celle des cycles et gradient thermiques sur la teneur en eau de l'isolant y sont discutées.

Abstract
This paper presents results on the insulation water content of different types of medium voltage extruded cables under simulated field conditions. The goal is to evaluate the amount of water penetration in the insulation when the cables are thermally cycled. Cables are XLPE or TRXLPE insulated, with or without a jacket, steam or dry cured. Conditioning of the cables was performed in a water tank, at 90°C maximum outside conductor temperature, $1xU_o$ applied voltage and no water in the strands. The influences of the jacket, thermal cycles and gradient on the insulation water content are discussed.

INTRODUCTION

Water has long been recognized to affect the performance and life of crosslinked polyethylene (XLPE) cables by means of water tree formation in the insulation [1,2]. The most common and cost-effective method to retard moisture penetration into the insulation is the use of a polymeric jacket [3,4]. Several studies [5,6] have shown indeed that jackets improve cable long term electrical performance and extend their service life. Ten years ago an EPRI economical study [7] even stated that the application of an overall linear low density polyethylene (LLDPE) jacket will add on average five years to cable life.

The aim of the present work is to evaluate experimentally this added time to cable life by measuring the evolution of the insulation water content of full-size jacketed and unjacketed cables under simulated service conditions. This correlation between insulation water content and cable life is expected, since water is the principal cable ageing factor [2]. There is no doubt that the presence of a jacket should delayed water ingress from outside the cable into the insulation under constant load conditions. However, the situation is less obvious when thermal cycling conditions are considered. This work was also extended to study the behaviour of steam and dry curing type XLPE unjacketed cables under the same conditions.

EXPERIMENTAL

The characteristics of the cable used in this work are given in Table 1. They are all 28 kV class with 750 kcm aluminum compact conductors and were made by three different manufacturers. Cables A, B and C are unaged and were dry-cured, while cable D was aged in service 14 years and steam-cured. Cables A and B are tree retardant XLPE (TRXLPE) insulated, the latter having a semiconductive linear low density polyethylene (LLDPE) jacket. The insulation of cables C and D is XLPE and these cables are unjacketed.

In order to study the water ingress into the insulation, the cable samples were immersed in a water tank and submitted to service conditions. They were formed in a U-shape of 4 m long with 50 cm termination ends and connected in series. No water was insert in the inner conductor prior or during aging. The tank, made of high density polyethylene reinforced outside with a steel armor, was filled with roughly 2000 liters of tap water which was not heated. Nine cable samples were installed in the tank plus two dummies, one unjacketed and one jacketed. The latter was selected to control the temperature as the jacket insulates thermally the cable giving rise to greater temperatures at the conductor, and the former served as a reference. Cables were heated by inductive current, 8 hours ON and 16 hours OFF, and $1xU_o$ (14,4 kV) was applied constantly. The maximum