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The design of power cables to operate at high electrical stress

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Sommaire

Les câbles remplis de fluide continuent de fonctionner de manière fiable en présence de contraintes nominales élevées: les contraintes dans les gaines de conducteurs en papier et en PPL sont de 15kV/mm et 18kV/mm respectivement. Les câbles et accessoires faisant usage de polyméres n'ont pas été en service suffisamment longtemps pour permettre de déterminer, de manière empirique, une valeur limite pour la contrainte nominale adoptée dans le cas des câbles remplis de fluide. Par conséquent, il va falloir recourir à des modèles mathématiques pour calculer la relation entre la contrainte nominale et la durée de service. Ce rapport décrit le développement et l'utilisation de ces modèles mathématiques pour les câbles en service.

Abstract

Fluid filled cables continue to display reliable operation at high design stresses: conductor screen stress for paper and PPL designs are 15kV/mm & 18kV/mm respectively. Polymeric cables, and accessories, have not been in service long enough to establish, empirically, a limiting value for the design stress as used for fluid filled designs. Consequently mathematical models are necessary to calculate the relationship between design stress and service life. The development and the use of these mathematical models for service applications are described in this paper.

Introduction

The introduction of crosslinking processes has permitted the continuous operating temperature of polymeric cables (XLPE & EPR) to be increased to 90°C, equalling that of fluid filled (FF) paper and polypropylene paper laminate (PPL) cables. However, to be competitive with paper and PPL cables [1], the diameters of extruded cables at both HV (33kV-190kV) and EHV (200kV-550kV) system voltages have to be significantly reduced to assist the dissipation of heat, give longer despatch lengths and hence reduce system costs towards that of FF systems.

The large diameters of polymer insulated cables result from low insulation design stress levels, which were historically associated with the level of quality achievable with earlier types of material and manufacturing plant [2]. Recent improvements in cable quality, for both XLPE & EPR, have been achieved through the use of in-house compounding and closed conveying systems. These advances have permitted the use of insulation thickness for 400kV XLPE cables in the range of 25 to 35mm compared to 20mm (15kV/mm) for the equivalent FF paper cable.

The primary insulant in the FF cable is the fluid which fully impregnates both the cable and its accessories. The stress at working voltage is obtained from the multiplication of the impulse design stress by the ratio of the working voltage (U_0) to the impulse voltage. This gives approximately a 2:1 design margin in the design stress at working voltage and, for a 400kV 2000mm^2 paper cable, results in a 20mm insulation thickness and a stress of 15kV/mm at the conductor screen (11.6kV/mm mean) [3]. A similar approach for a PPL cable enables a stress of 18kV/mm [4] at the conductor to be used. The latter values largely explains the excellent service performance of FF cables at HV and EHV (60 years and 30 years respectively).

Polymeric cable performance is significantly different as the insulation thickness is limited by the stress at the AC working voltage necessary to achieve the design life of nominally 30 - 40 years and not by the lightning impulse voltage. Thus for polymeric (XLPE & EPR) cable systems to become reliable at HV and EHV, the determination of a safe design stress at working voltage is vital. Polymeric cables, and accessories, have not been in service long enough to establish an empirical limiting value for the design stress. Consequently mathematical models are necessary to calculate the relationship between design stress and service life. The development and the use of these mathematical models for service applications are described in this paper.