EVALUATION OF FIELD-REJUVENATED MEDIUM-VOLTAGE EXTRUDED CABLES

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ABSTRACT

Medium-voltage extruded cables rejuvenated in the field were removed from service and analyzed for their electrical performance. The cables consisted of two triplexed, 28-kV class, cross-linked polyethylene-insulated (XLPE) cables, injected with silicone in their inner conductor 11 and 16 years ago respectively. These cables were in service for a total of 33 and 19 years in service respectively, i.e. before and after injection. Also, for comparison one non-injected cable was retrieved from each location or line and analyzed in the same way. The evaluation consisted of AC breakdown (ACBD) tests performed in accordance with ICEA specifications, measurement of the insulation water content, and water tree analysis near the failure sites. The results indicate that the ACBD voltage is high but that it was slightly higher for one injected cable by some 25% compared to its reference. From the other injected cable, it was found that, strangely, silicone fluid was still present, particularly in the conductor of one phase, after 16 years, which was not the case for the other two phases. One of the injected cables shows much lower insulation water content as well as far fewer and shorter water trees than the reference cable.

KEYWORDS

Medium-voltage extruded cables, silicone injection, field experience and evaluation.

INTRODUCTION

Distribution cable rejuvenation has been considered by several electrical utilities [1-7] as an economical alternative to replacement. Cable rejuvenation consists in injecting into the conductor strands customized silicone fluids [8, 9], which with time will diffuse into the insulation, slow down water tree growth and improve the electrical performance of extruded medium-voltage (MV) cables, particularly steam-cured ones [10]. Providers of these silicone fluids expect that the life extension of these cables will exceed 20 [11] and even approach 40 years [9].

In the 1990s, Hydro-Québec started looking into MV cable rejuvenation and since then has performed tests in laboratory [12, 13] and pilot projects in the field [14]. To pursue this evaluation and to verify the long-term efficiency of silicone rejuvenation, some cables were removed from service 11 and 16 years after injection. This study presents the characterization of these cables in comparison with non-injected cables taken from the same lines. Characterization examined residual dielectric strength, insulation water content and treeing analysis.

EXPERIMENTAL

The cables removed from service share the following characteristics: triplex, 28-kV class, aluminum compact conductor, XLPE-insulated, steam-cured, concentric neutrals and no jacket. The cables come from two different areas of the Hydro-Québec network, namely A and L, but all were installed in duct systems. The first cable (AR) has a 500-kcm conductor and was injected with silicone by a service provider 11 years ago. A non-injected cable (ANR) from the same line luckily made by the same manufacturer A, also in 1977 was removed to serve as a reference. The second cable (LR) has a 750-kcm conductor, was injected 16 years before removal and was made by manufacturer B in 1991. Unfortunately, it was not possible to find the same cable for the reference on that line, only a cable (LNR) on a branch, which was made by another manufacturer (C) in 1988. Obviously, in this case the comparison will be difficult.

As soon as these cables were removed from service, they were cut and subjected to 60 Hz AC breakdown (ACBD) tests. These tests had to be performed as fast as possible to prevent drying of the insulation, which has a significant impact on the ACBD voltage [15], and also had to be representative of service conditions. The ACBD tests were performed in accordance with ICEA specification S-94-649 [16] using water terminations on cable samples with an active length of 16,6 m (roughly 10-15% of their length in the field). One cable per phase, i.e. three samples of each cable, was tested.

Immediately after the ACBD tests, pieces of cable were cut near the failure for water content measurements of the insulation and water tree analysis. A moisture meter, based on the Karl-Fischer titration method [17] was used to measure the insulation water content. For these measurements, two samples were taken diametrically opposed near the breakdown site and cut into pieces measuring 7x7x20 mm that were representative of the entire insulation thickness to avoid misleading local measurements [18]. The water tree analysis, based on AEIC CS8 specification [19], was performed on ten 635-µm-thick helicoidal ribbons ("slinky") cut near the failure site and stained with methylene blue as per general practice. In this analysis, only water trees of ≥250 µm were considered.

RESULTS AND DISCUSSION

AC Breakdown (ACBD) strength

Fig 1 and Table 1 give the ACBD results for each cable sample. Note that all the breakdowns occurred in the active part of the cable samples, i.e. no termination failure, and the ACBD strength is calculated by dividing the breakdown voltage by the insulation thickness near the failure point. First, the results show that the ACBD strength is quite high, roughly between 5 and 9 Uo (phase-to-ground voltage: 14,4 kV), for field-aged cables A and L after 31 and 19 years in service respectively, and compared to similar cables giving roughly 4 Uo or 8,5 kV/mm immediately after removal [15]. Injected cables AR gave 12,9 kV/mm on average, while the reference non-injected cable gave 10,3 kV/mm. The silicone rejuvenation, 11 years after the injection, contributed to