Accelerated Aluminum Corrosion upon Water Ingress in Damaged Low Voltage Underground Power Cables.

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ABSTRACT

Condition assessment and degradation mechanisms in Low Voltage (LV) cable systems are under investigation. When damaged LV cables are exposed to water, corrosion of aluminum conductors may occur. Under influence of potential differences, the water becomes caustic and effectively removes the passive oxidation layer. The corrosion of the exposed aluminum can continue unhindered, eventually leading to a disturbance. The corrosion process was investigated under different experimental configurations in a laboratory setup. The development of a fault was observed optically during which electric current profiles were recorded. The tests show rapid development of corrosion and give further insight into this degradation mechanism.

KEYWORDS

Low voltage, underground power cables, degradation, aluminum, corrosion.

INTRODUCTION

Particularly in rural areas, electricity distribution is dependent on underground power cables. Reliability and valuation of these systems is of importance for grid operators and owners. Condition assessment is widely applied to maintain quality of supply and prevent outages. As higher costs of an outage is associated with higher number of customers connected, condition monitoring is at present mainly focusing on higher voltage levels. In high voltage equipment, partial discharges have been found to be a significant aspect of cable and accessory degradation.

Low Voltage (LV) cables generally have only several tens of customers connected. An outage in the LV grid has a minor impact on the grid operator's average customer-minutes-lost. Therefore, so far little effort was put in the assessment of LV cable condition and the study of degradation mechanisms. However, due to the lack of redundancy and direct customer connections to the cable, costs associated with the localization and repair of LV failures are higher compared to medium and high voltage cables. Furthermore, an average increase, though slow, has been observed in the number of LV faults in the Netherlands. These aspects motivate to put more effort into investigation of degradation mechanisms and applying condition monitoring in the LV grid.

LV cable failures have often an intermittent nature. A failure causes a fuse to break, while this fuse can be replaced afterwards without directly breaking again. The fuse may remain intact for hours up to months until the same failure reappears. The cycle may continue until the operator decides to investigate. This causes repeated outage time to the same customers and corrective action needed from technicians. The fact that faults occur with such characteristics may originate from the robustness of LV cables. That is: a damaged cable may remain in operation for long until degradation mechanisms instigated with the damage have led to a disturbance. In general, insulation thickness is 3 mm between conductors with plastic insulated cables. The voltage typically applied in LV systems (400 V_{rms}) is then insufficient for a flashover. Therefore, significant damage (causing conductors to break or touch) is needed for a disturbance to occur directly. However, LV cables may often be damaged without such conditions. In that case, degradation mechanisms may start or accelerate, possibly leading to a disturbance in the future.

For economic reasons, aluminum conductors have become the most attractive alternative to previously more often used copper conductors. In many cases, LV cables are completely or partly submerged in water due to ground water levels. In such cases, corrosion could occur. In previous research, corrosion of LV cables in relation to a steel screen has been reported [1]. Grid operators have reported what appears to be a corrosion process on aluminum conductors in LV cables. A powder-like white substance is formed with large volumes. This substance is released locally from a damaged location, and extends much wider than the cable cross-section. In these cases, part of the aluminum conductor cross-section has disappeared over lengths up to several decimeters. An illustration is given in figure 1. The underlying process is so far not well understood.

To study the corrosion phenomenon, a laboratory setup was developed. Cable samples with artificial damage were tested. In the following section, the background of aluminum corrosion in LV underground power cables is

Fig. 1: Example of a cable section affected by aluminum corrosion. Unattached aluminum hydroxide is removed to show the extent of aluminum removal by the process.