Effects of Loss of Coolant Accidents (LOCAs) on dielectric properties of nuclear LV cables

Simone Vincenzo **SURACI**, Davide **FABIANI** Laboratory of innovative Materials for Electrical Systems (LIMES) - Department of Electrical Engineering - University of Bologna, Italy, simone.suraci@unibo.it, davide.fabiani@unibo.it

☒ **Young Researcher** (Proved full-time engineering and science university researchers and Ph.D.students under 35 YO)

ABSTRACT

This article presents the electrical and chemical characterization of coaxial low-voltage cable for nuclear applications. Cables were initially aged under accelerated conditions by using radiation and high temperatures. Then, they were subjected to a Design Basis Event (DBE) which included a loss of coolant accident (LOCA) simulation. Results claim that the selected aging conditions differently modify the electrical properties (complex permittivity and conductivity) of the cables. In particular, the use of tanδ at high frequencies (100kHz) is proposed as an aging marker since it correctly follows the aging evolution and severity of the tested cables.

KEYWORDS

Nuclear cables, LV cables, radiation aging, LOCA simulation, NDT

INTRODUCTION

Low voltage cables are extensively used inside nuclear power plants (NPPs) mainly for the delivery of signals and data (instrumentation and control -I&C- cables). During their lifetime, cables may be subjected to a multitude of environmental stress e.g., radiation, high temperature and moisture.

Among the different types of cables used in NPPs, the ones important to safety are required to fulfil their operation even after the occurrence of a nuclear accident. For this reason, the qualification of this kind of cables is very complex and implies various steps which make up the so-called *Design Based Event (DBE) simulation* in accordance with IEEE 383 standard [1].

During a DBE simulation, the cables are subjected to an abrupt increase of temperature and pressure along with huge dose rates in a short period of time. This procedure simulates typical conditions occurring during a loss of coolant accident (LOCA).

The evaluation of the proper operability of the cables after a LOCA is a key factor for guaranteeing the required high safety standards inside NPPs. Up to now, the suitability of LV cables to operate inside the power plant is verified by means of tensile tests. In particular, it was demonstrated that if a cable owns an elongation-at-break value higher than 50% (absolute value), it would be able to withstand a Loss of Coolant Accident (LOCA) and still properly operate under normal conditions [2]. Nonetheless, the need to find innovative non-destructive testing techniques for the condition assessment of these cables accelerated the Research interest towards electrical tests. Among those, dielectric spectroscopy proved to be a valuable candidate for the condition monitoring of LV cables, having shown good correlation with correspondent elongation-at-break values.

Thus, the aim of this paper is twofold. On one hand, it aims at quantifying the impact of a LOCA on some of the most interesting cable electrical parameters i.e., complex permittivity and conductivity. On the other hand, the suitability of the dielectric spectroscopy technique is also evaluated to assess the cable condition after a LOCA.

EASE OF USE

Cable samples

Samples here analysed are low-voltage I&C coaxial cables specifically designed for the Horizon 2020 TeaM Cables project [3]. Morphology of the investigated cables is reported in Fig. 1. Each cable specimen is about 50 cm long. Specimens are made of five concentric parts:

1. Conductor – Copper (the innermost);
2. Primary insulation – Silane crosslinked polyethylene (Si-XLPE);
3. Polymeric film;
4. Shielding – Copper wire braid;
5. Outer sheath – Low Smoke Zero Halogen.

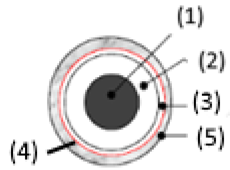

Fig. 1: Morphology of the investigated coaxial cables

The primary insulation is a silane crosslinked polyethylene stabilized with 1 phr of primary antioxidant (phenol-based) and 1 phr of secondary antioxidant (thioether-based). Note that such concentration of antioxidant is uncommon and very high in comparison to typical values used in LV cables. This leads to an increase of endurance of cables by reducing the degradation mechanisms caused by aging.

In order to properly perform electrical tests on the primary insulation, layers #3,4,5 were removed from the cable before testing. In addition, a 10cm-long external copper wire braid was placed on the primary insulation and it was used as signal electrode for electrical characterization tests.

Accelerated aging

Cable samples were aged under radiation and high temperature in order to simulate typical nuclear environment stresses on cables. Aging parameters were chosen in order to mimic equivalent damage on samples due to aging in a shorter time (accelerated aging). For this reason, stresses are way higher than typical ones present inside NPPs. In particular, in this work, two aging temperatures (47°C and 87°C) along with a constant dose rate (7.2 Gy/h) were applied to the cables for a total of 678 days (1.85 years).

Tab. 1: Aging parameters of cables.