Post-irradiation effect investigation on low-voltage XLPE cables through dielectric spectroscopy

Simone Vincenzo **SURACI**, Davide **FABIANI**, DEI – University of Bologna (Italy), simone.suraci@unibo.it, davide.fabiani@unibo.it

ABSTRACT

This paper deals with the aging of low voltage XLPE power cables under different environmental stresses (e.g. high temperatures and irradiation doses). The evolution of degradation of these cables has been investigated by the means of a non-destructive monitoring technique, i.e. the dielectric spectroscopy. High level of dose rates brought to diffusion limited oxidation phenomenon which has been evaluated and discussed. Post-irradiation effects inside the primary insulation, have been highlighted by performing tests after five years of storage in an uncontrolled environment. In conclusion, it is shown that materials aged under different aging conditions, can show quite similar electrical response after a 5-year storage period due to post-irradiation effects.

KEYWORDS

Post irradiation effect, qualification of cables, nuclear power plants cables, diffusion limited oxidation.

INTRODUCTION

In the last decades, more and more research has been focused on the qualification of electrical devices and assets in power plants, like e.g. cables, through non-destructive techniques which are cheaper and easier to be applied, even on-service.

This topic is particularly important for nuclear power plants (NPPs) which are supposed to have their life extended up to other 40 years in order to postpone the decommissioning of the plant whose costs can be really high.

One of the key components whose substitution has not been planned during application life is represented by low voltage cables which are used to deliver not only power but also instrumentation and control data. Since it has been estimated that each NPP owns about 1500 km of LV cables, the qualification of all this huge number of elements has become a critical issue for NPPs life extension [1, 2].

Up to now, different condition monitoring (CM) techniques are available and, in some cases, standardized. Many of those are laboratory condition monitoring techniques (e.g. Elongation-at-Break (EaB), Oxidation Induction Time (OIT) and density) but, as known, the most desirable feature for a CM technique is that it can be performed *in situ*. This would allow the evaluation of the state of the cable in the same place where it is located without the need to remove a small length of it, which in some cases could be non-representative of the whole cable, to the laboratory.

Undoubtedly, another feature for an effective CM technique is the ability not to damage the component under investigation.
Due to the huge amount of cables to be qualified for each plant, the use of non-destructive CM techniques is desirable to save time and costs.
Among these techniques, dielectric spectroscopy is one of the most promising, since it allows cable degradation state to be evaluated *in situ* without damaging the cable.

As known, environmental stresses (e.g. temperature and radiation) lead to the degradation of the cable and, in particular, of its electrical insulation by the action of oxygen. If these stresses are particularly high, for example during a LOCA, oxygen in the air can be not enough to catalyse degradation reactions so that oxygen molecules can bond only on the outer layer of the insulation, preventing the oxidation to diffuse in the bulk. This effect is known in literature as diffusion limited oxidation (DLO). This leads to a non-homogenous degradation throughout the insulation and to the creation of surface cracks which can easily reduce elongation-at-break (EaB) of these cables to values lower than the 50% allowed for qualification by standards [3].
If a huge number of radicals remain trapped inside the crystalline phase, e.g. after an important irradiation absorption by the polymer, material properties can evolve even after the irradiation source is turned off.
This phenomenon, called post-irradiation effect, can affect the reliability of the cables qualification tests if they are conducted only immediately after a nuclear accident or LOCA.

This paper investigates the evolution of electrical properties of low voltage cables used in NPP aged through different environmental stresses (irradiation and high temperatures).
Moreover, the same cables have been tested again in order to evaluate the possible post-irradiation effect and the long-term dielectric response of cables aged under different aging conditions.

EXPERIMENTAL SETUP

Specimens

The samples investigated are low-voltage I&C coaxial cables with XLPE insulation used in NPPs made by Alcatel. Cables have been provided for EU FP7 ADVANCE Project purposes. Structure of the analysed cables is reported in Fig. 1. Specimens are made of four concentric parts:

1. Conductor – Copper – Ø = 0.6 mm^2 (the innermost);
2. Primary insulation – XLPE – thickness 1.6 mm;
3. Shielding – Copper wire braid;
4. Outer sheath.

The outer sheath has been removed for analyses so that it does not affect the measurements.