AGING ASSESSMENT OF XLPE LV CABLES USED IN NUCLEAR POWER PLANTS

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

Anne **XU**, Sébastien **ROLAND,** Xavier **COLIN**; PIMM – Arts et Métiers ParisTech, (France), anne.xu@ensam.eu, sebastien.roland@ensam.eu, xavier.colin@ensam.eu

ABSTRACT

This paper investigates the evolution of electrical and physico-chemical properties of low-voltage power cables for nuclear application subjected to both temperature and radiation aging. Electrical response is evaluated by the means of the dielectric spectroscopy technique while the physico-chemical and mechanical changes are analysed at different structural scales by five complementary techniques (FTIR spectroscopy, DSC, OIT, swelling measurement and micro-indentation). All these techniques are shown to be appropriate for the evaluation of the radiochemical aging development on LV cables, suggesting the effectiveness of dielectric spectroscopy as a non-destructive technique for on-site cable diagnosis.

KEYWORDS

XLPE aging, Gamma radiation, nuclear LV cables, low-voltage cables, antioxidant migration, polymer oxidation, dielectric spectroscopy.

INTRODUCTION

Low voltage cables are widely used in nuclear power plants (NPPs) for power transmission, control of equipment and instrumentation, communication (I&C) of signals and data. It has been estimated that inside each NPP there are about 1500 km of cables; since most of the NPPs built during the '80s and '90s are now reaching their end-of-life point, electric utility companies are trying to extend the NPPs operating life up to other 40 years. To do so, low-voltage (LV) I&C cables qualification is a key problem due to the fact that standards set qualification of cables only through destructive techniques [1-2].

As known, the design of nuclear cables can differ depending on the applied voltage and on the specific application (control, power or instrumentation). In any case the most sensitive part in terms of aging is the electrical insulation which surrounds the conductor whose extensive degradation can lead to the failure of the cable. Insulation is made by using polymers which can be filled of different kinds and concentration of additives, above all antioxidants and flame retardants, which can reach very high concentrations (up to 60% w/w) in low voltage power cables.

This research is part of a novel EU Project called "TeaM Cables" which aims at providing NPP operators a novel methodology for efficient and reliable NPP cable ageing management by developing cable aging models and methodologies for non-destructive testing techniques. The materials chosen for analyses inside the TeaM Cables project are the most widely used in power plants:

- Crosslinked Polyethylene (XLPE)
- Ethylene-Vinyl Acetate / Ethylene propylene diene copolymer (EVA-EPDM)

This paper studies the behavior of both electrical and chemical properties with aging on LV power cables made with XLPE insulation. To do so, tests are conducted by the means of both non-destructive (electrical) and standardized destructive techniques (physico-chemical and mechanical). Dielectric spectroscopy technique has been used to analyze the electrical behavior of the insulation and five complementary techniques (FTIR, DSC, OIT, swelling measurement and micro-indentation) have been employed to assess the physico-chemical and mechanical changes. In the end, correlations between these experiments have been carried out.

EXPERIMENTAL SETUP

Specimens

The samples here analysed are low-voltage I&C coaxial cables with XLPE insulation used in NPPs, especially designed for the project. Morphology of the investigated cables is reported in Fig. 1. Specimens are made of five concentric parts:

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

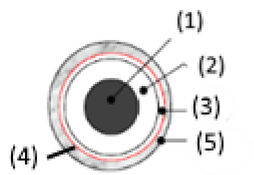

Fig. 1: Morphology of the investigated coaxial cables

The primary insulation, in particular, is a silane crosslinked polyethylene stabilized with 1 phr of primary antioxidant (phenol-based) and 1 phr of secondary antioxidant (thioether-based).

Each cable specimen is about 50 cm long.

Accelerated aging

Aging was performed in the Panoza facility at UJV Rez, Czech Republic. A ^{60}Co γ-ray source was used to fulfil the process. The dose rate set for the aging was 70 Gy/h at 50 °C. Specimens were aged for 200 days and sampling was made about every 40 days. So that, the maximum absorbed dose is 286 kGy.

Electrical measurements

Electrical properties, in particular the complex permittivity, were investigated by means of dielectric spectroscopy technique with a Novocontrol Alpha Dielectric analyser.