Study of the thermo-oxidative ageing of crosslinked polyethylene for HVDC applications

Justine **BILLORE** (1,2,3), Jean-Louis **AUGE** (1,3), Sébastien **PRUVOST** (2), Olivier **GAIN** (2), Charles **JOUBERT** (1), Arnaud **ALLAIS** (3), Michaël **DARQUES** (3), Wilfried **FRELIN** (3)

(1) Laboratoire Ampère, UMR 5005, Villeurbanne, France, justine.billore@univ-lyon1.fr , jean-louis.auge@univ-lyon1.fr , charles.joubert@univ-lyon1.fr

(2) Laboratoire IMP, UMR 5223, Villeurbanne, France, sebastien.pruvost@insa-lyon.fr , olivier.gain@univ-lyon1.fr

(3) SuperGrid Institute, Villeurbanne, France arnaud.allais@supergrid-institute.com, michael.darques@supergrid-institute.com, wilfried.frelin@supergrid-institute.com

ABSTRACT

Different physical and chemical ageing markers due to thermal ageing of the synthetic insulation of HVDC cables are identified. For that purpose, the variations of different physical and chemical properties with thermal ageing are analyzed. It was found that crystallinity, oxidation and chain scissions during ageing are key parameters to quantify the XLPE ageing.

KEYWORDS

Cable insulation – DSC – FTIR – HVDC – TGA – thermal ageing – XLPE

1. INTRODUCTION

European governments are preparing their energy transition by aiming at increasing the share of renewable energy to reduce greenhouse gas (GHG) emission. The "20-20-20" target has three main objectives[1].

- The amount of electricity from renewable energy should reach 20% of supplied energy.
- The emission of GHG should be reduced by 20% as compared to 1990 level.
- The power efficiency should be improved by 20%.

To fulfill these ambitious objectives, the structure of European power systems must be adapted.

Large renewable energy production areas are far away from consumption areas. Point to point long distance connections already exist in some industrialized countries like the USA, China, Japan and Europe. These links are onshore or offshore and involve transport under high voltage DC current (HVDC). HVDC links can increase the power transmission distance. In fact, the transportation distance may be increased from several tens of kilometres with AC cables (HVAC) to hundreds of kilometres with HVDC links, at a better economical cost [1].

Reliability and life span of HVDC cables are major issues. Indeed, local defects in the insulation material will appear and evolve over time based on the history of electric fields and load conditions [2]. Local enhancement of electric fields or thermal runaway may, in particular, be due to the presence of crosslinking by-products [3].

Ageing studies of cable insulation have already been carried out, focusing on electrical ageing markers like space charges or partial discharges [1]. The identification of physical and chemical markers for the ageing of HVDC cables has been conducted by a succession of complementary approaches to understand the origin of these phenomena. In this paper, several physical and chemical ageing markers to monitor thermal ageing of the insulation are proposed.

2. CROSSLINKED POLYETHYLENE

Crosslinked polyethylene has been used since 1960 for cable insulation due to its good dielectric, mechanical and thermal properties. Mass Impregnated (MI) insulation cables have a relatively long production cycle and may be manufactured only in a few specific plants in the world at a high cost. Progressively switching to XLPE extruded cable allows using relatively widespread plants for a cheaper cost and faster production. On the utilities side, the main advantage of XLPE over MI is its higher service temperature under DC (70 °C vs. 55 °C).

XLPE is based on Low Density Polyethylene (LDPE). The crosslinking reaction consists in creating bridges between polymer chains to obtain a three-dimensional network by forming covalent bonds between polymer chains.

Crosslinked polymers are generally insoluble and infusible. Furthermore, crosslinking enhances the shock resistance, creep resistance and reduces the extent of cracks. In return, it reduces the elongation at break but has no influence on the tensile strength and density.

a. Structure

Crosslinked polyethylene is a semi-crystalline material. It is composed of two phases, an amorphous part where there is no long range organization of molecules and a crystalline part, which is ordered, usually in the form of radially extending spherulites (Figure 1).

1 http://ec.europa.eu/clima/policies/package/index_en.htm