Weibull analysis as a tool to describe DC breakdown performance and distribution in polyethylene for HVDC applications at laboratory scale

Raphael **GUFFOND** (1,2), Dimitri **CHARRIER** (1), Christelle **MAZEL** (1), Daphné **MERLE** (1), Arnaud **ALLAIS** (1)
1: Nexans Research Center, 29 rue Pré Gaudry, 69007 Lyon Cedex 07, FRANCE
raphael.guffond@espci.fr, dimitri.charrrier@nexans.com, christelle.mazel@nexans.com, daphne.merle@nexans.com, arnaud.allais@nexans.com
2 : ESPCI, 10 rue Vauquelin, 75231 Paris Cedex 05, FRANCE

ABSTRACT

A tool at laboratory scale is necessary for characterizing insulating materials dedicated to high voltage (HV) applications before fabrication at full scale. The aim of this work is to give a method for identifying electrical performances of different materials and compositions. Materials are based on polyethylene, and can be cross-linked or not, and contains additives. The method consists in making thin plates at 100 micrometer thick and submit them to HV DC breakdown tests at room temperature: i) ramp up voltage, ii) reversal polarity after poling. The breakdown voltages were analyzed with the Weibull function to extract the scale parameter α and the shape parameter β. Results for cross-linked and not-cross-linked materials are shown in graphics β=f(α) in confidence contours and are confronted with optical observation of agglomerates in the case of dark additives.

KEYWORDS

DC dielectric strength; Weibull statistics; Performance evaluation; Shape parameter

INTRODUCTION

The use of cross-linked polyethylene (XLPE) as insulating material has since many years become the industry standard for high voltage and extra-voltage AC cables. The main reasons are the combination of attractive cost (materials and process), low cable weight, appropriate electrical and thermo-mechanical properties and reliability [1]. However, for DC application, the development of such extruded insulation is still hampered due to its weakness resulting from the dependence of electrical resistivity of the polymer on temperature and DC electric field and the effect of space charge accumulation in this material. Due to this behavior, there is a risk of distortion of the electrical field throughout the insulation thickness which may lead to a premature failure of the cable [2]. In consequence, significant developments were initiated by polymer suppliers and cable manufacturers to achieve reliable HVDC transmission system. And it has been highlighted that the performance of insulating material depends also on its morphology, which will be affected by additives.

In the frame of this work, we distinguish two groups of extruded insulation:

- pure polymeric material,
- polymeric material with additives.

We consider that insulating grade XLPE used in HVAC cables typically already contains some additives such as stabilizer (anti-oxidant), cross-linking agent (peroxide) before crosslinking and its decomposition by-products after crosslinking.

A lab method has been developed to study the electrical behavior of polymeric materials under DC conditions in order to speed up the screening of insulating polymer for DC application in combination with a better understanding of their electric withstand characteristic. The method consists in making thin plates at 100 micrometer thick and submits them to HV tests. The tests are i) DC breakdown voltage V_{bd} obtained after a ramp at 0,5 kV s^{-1}, ii) inverse polarity breakdown voltage V_{bd} obtained after a 24h 5 kV DC poling. In both cases, the HV generator stops the voltage as soon as a short circuit is detected due to local breakdown. All tests are performed at room temperature.
A Weibull statistical analyze was then applied to the breakdown voltage measures.

MATERIALS AND METHOD

The materials investigated are shown in the Table 1, they are either commercial grades or home-made. The basic material, a low density polyethylene (LDPE) is also characterized. Additives such as anti-oxydant, dicumyl peroxide (DCP), tert-butyl cumyl peroxide (tBCP), or carbon blacks (CB) are present. Both DCP and tBCP are decomposed in LDPE resin under a thermal treatment forming a cross-linked (XL) polyethylene network. DCP is present at 2% in so-called material HVDC1 and 1% in HVDC2. A material was prepared consisting in LDPE blended with nanofillers (CB) and tBCP, called NFa. Another one contains CB and DCP, called NFb.

Table 1: Materials with reference names

Material	Reference name
LDPE	LDPE
LDPE+DCP (2%)	HVDC1
LDPE+DCP (1%)	HVDC2
LDPE+DCP (2%)	HVAC
Process a LDPE+CB+tBCP	NFa
Process b LDPE+CB+DCP	NFb