ANALYSIS OF THE RESISTIVITY LOSS OF AGED PVC CABLES AND EFFECTS ON THEIR DIELECTRIC STRENGTH

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ABSTRACT

Cables with insulation in PVC are the object of a study to analyse the reasons of their resistivity decrease and the effect on their dielectric strength.

After a short context presentation and a recalling of the main properties of PVC and of aging phenomena in PVC, dielectrics and physicochemical characterisations done are going to be exposed. Dielectric spectroscopy, dielectric strength and breakdown measurement, differential scanning calorimetry, dynamic mechanical analysis and infrared spectroscopy results are presented.

Physicochemical analyses show that no migration of plasticizers occurs and that heat stabilizers are still present. Differences in dielectric properties are revealed but the dielectric strength is not affected.

KEYWORDS

PVC, MV cable, aging, resistivity loss, dielectric strength.

INTRODUCTION

Context

PVC insulated cables remain operated in certain EDF installation. An improvement in the economic management of possible maintenance can be done, specifically on radial field, medium voltage cables operated at 6.6 kV.

For some of them, a decrease of insulation resistance has been detected. However, recent EDF R&D studies have shown that despite this loss of properties, the dielectric strength of the material remains good enough to withstand the voltage.

EDF R&D has chosen to start a new study in June 2010 to better understand the phenomena leading to the variation of the material conductivity. This study will combine dielectric characterization and physicochemical characterization. This paper gives the results of the first experiments done on a sample of aged cable

PVC for cable (plasticizers / thermal stabilizers)

PVC used as insulation in MV cable must have a specific formulation in good agreement with the function that it will have to assure. For this reason the main constituents are always from the same family whatever the manufacturer is. Plasticizers, heat stabilizers and fillers are the principal constituents, with the PVC resin, of the material.

Plasticizers are typically phtalates and most often phtalates with a C8 to C13 aliphatic chain. This way the plasticizers give a good accommodation between its electrical properties and its physical properties (volatility, aging behaviour). From 78°C for pure PVC, Tg reach values comprise between -30 and 70°C with plasticizers. Plasticizers work by decreasing the interaction forces, like Van Der Waals or hydrogen interaction, between the polymer chains.

Heat stabilizers play an important part in the aging of PVC. Indeed they are used to inhibit the dehydrochlorination phenomenon that occurs in PVC during the lifetime of the material when exposed to an elevated temperature. Heat stabilizers used in electrical application are lead-based compounds. The choice of this kind of stabilizers is also led by their good electric properties (high resistivity) and by their large area of efficiency.

Fillers are used to decrease the production price of the PVC and to give it good mechanical properties. In PVC the fillers are mineral. They mostly contribute to the improvement of the dielectric properties by playing an effect of barrier for the charge displacement.

Aging of PVC

There are three main degradation mechanisms in PVC. The first one is the dehydrochlorination. It means that HCl molecules are released from the PVC polymer chain under the effect of temperature. This reaction may begin at relatively low temperature (about 70°C) but with slow kinetic. At temperature above 100°C, there is a runaway of the phenomenon by autocatalysis. Different authors talk of a beginning temperature of dehydrochlorination of 93°C [1] and 100°C [2]. Dehydrochlorination is a mechanism highly dependant on a lot of parameters as the temperature, the time of exposition or the formulation of the PVC. When it occurs and when thermal stabilizers are consumed, studies have showed that it is possible to link the heat stabilizers consumption with the decrease of insulation resistance [3]. Dehydrochlorination in our case may be followed by coulometric titration of lead chloride which is produced when heat stabilizers trap HCl [4].

The second degradation mechanism is the migration of the plasticizers. It may be a lost of plasticizers or an inter-diffusion of plasticizers of insulation and jacket. Many parameters let us thinking that in our case the phenomenon is secondary: first, at temperature less than 120°C the loss is controlled by the evaporation of the plasticizer [5]. But the PVC in the cable is confined (see figure 1) and is not in contact with atmosphere, preventing it to this evaporation. Measurement of plasticizers rate in old PVC have also shown that it was close to the original [6]. Inter-diffusion of plasticizers is an other way of aging.